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Salute Trieste!

Our preoccupation with the exploration of space should not lead us to neglect terrestrial achievements. And so we here salute M. Jacques Piccard and Lieutenant Don Walsh of the U.S. Navy for their record-breaking dive in the bathyscaphe *Trieste* to the bottom of the Challenger Deep in the Marianas Trench on 22–23 January. In descending 35,780 ft. (the figure given after applying corrections for temperature and salinity), they are believed to have reached Earth's deepest ocean bed.

This achievement will rank equal with the conquest of Everest and the attainment of the Poles. Purists may object to this statement, because of the degree of technical assistance given to the divers (no doubt mountaineers forfeit their amateur status if they employ helicopters, balloons or rockets, although they are apparently allowed to accept and use precision watches and cameras, oxygen equipment, etc.), but unfortunately the use of a bathyscaphe was inevitable.

The real importance of *Trieste*'s dive lies not in the breaking of a record, but in the demonstration that man can now explore anywhere beneath the seas. Explore —and prospect—perhaps later also mine and farm. The possibilities—scientific, commercial and military—are enormous.

What is the importance of the descent to astronautics—for are not all the facets of man's knowledge and experience interrelated so that they illuminate one another? We might consider the use of a much-modified bathyscaphe for the exploration of Jupiter. We might draw a parallel between the crew of a bathyscaphe and that of a spaceship. But there is something more important—evidence of life was found at the bottom of Challenger Deep, where the pressure is over 7 tons/in^2.

If we accept the hypothesis that all terrestrial forms of life had a common origin —a common terrestrial origin—then this is indeed further evidence of how our life can adapt itself to the most forbidding conditions. The probability that some of the lower organisms will adapt to Mars or Venus is increased. Moreover, only the rash would now dare to prophesy that no life will be found on these planets, or, if found, will not adapt itself to terrestrial conditions.

G. V. E. THOMPSON.

ESTABLISHMENT OF A CIRCULAR SATELLITE ORBIT BY DOUBLE IMPULSE*

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ABSTRACT

This note deals with the optimum direction of launch and the staging of a two-stage satellite carrier required to establish a given payload in a circular orbit of prescribed radius using a minimum amount of fuel. It is shown that, for the ideal model of vacuum flight over a rotating, spherical Earth, and impulsive thrust application, the ratio of stage specific impulses is the governing parameter. Horizontal launch towards the east is best above a certain value of the specific impulse ratio. When this ratio drops below a critical value a vertical velocity component is required at launch (first stage burn-out). It is also shown that fuel consumption has a maximum for a finite radius orbit.

LIST OF SYMBOLS

a	=	V/c_1
b	=	$(\sqrt{r_2 g_2} - v_2)/c_2$
c_1, c_2		Effective exhaust speeds of first and second stage, respectively.
g		Gravitational acceleration.
g_1, g_2		g at r_1 and r_2, respectively.
k_1, k_2		$\frac{m_{10} - m_{1P}}{m_{1P}}, \frac{m_{20} - m_{2P}}{m_{2P}}$, respectively.
m_{10}, m_{20}		Mass of unburnt first and second stage, respectively.
m_{1P}, m_{2P}		Mass of propellent of first and second stage, respectively.
m_P	=	$m_{1P} + m_{2P}$.
m_L		Mass of payload.
p	=	$\left[1 - \left(\frac{r_1}{r_2}\right)^2\right]^{-1}$
r_1		Radius of Earth.
r_2		Radius of satellite orbit.
v_1		Initial speed after first impulse.
v_2		Speed at apogee before second impulse.
v_E		Initial speed due to Earth's rotation.
v_e	=	$\sqrt{2g_1 r_1}$.
v_g	=	$\sqrt{g_1 r_1}$.
A	=	$2\mu\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$.
G		Universal constant of gravitation.
M		Mass of Earth.
V		Speed increase due to first impulse.
γ		Latitude angle of launch location.
μ	=	GM.
ω		Angular speed of Earth.
β		Launch angle.

I. INTRODUCTION

THE general performance problem of the ascent of orbital vehicles has been discussed by Ehricke.[1] He noted three possible ascent trajectories: (1) powered-all-the-way (PAW) ascent; (2) elliptic ascent; (3) ballistic ascent. Fried[2] has investigated the optimum thrust direction programme for the case of the PAW ascent under prescribed thrust. More recently Okhotsimskii and Eneev[3] have shown that the linear thrust direction programme, found by Fried, as well as impulsive thrust are optimum. Similar results hold when the thrust is bounded as was demonstrated for a class of such optimum problems by Leitmann.[4] The present paper deals with the optimum ascent into a circular orbit by means of two thrust impulses, *i.e.*, elliptic or ballistic ascent.

It is required to place a payload of prescribed mass into a circular orbit of given radius about the Earth by means of a two-stage rocket. Launching is to take place from a specified location on the Earth, which is assumed spherically symmetrical and rotating with constant angular velocity. It is further assumed that both stages burn instantaneously (impulsively), one at the surface of the Earth, the second at the instant satellite altitude is reached (apogee of the required Kepler ellipse of ascent). Aerodynamic effects are neglected. It is desired to find that direction of launch (first-stage-burn-out) and the corresponding ratio of stage masses such that fuel consumption be minimum.

II. STAGING

The speed increase resulting from first impulse is:

$$V = c_1 \ln \frac{m_L + m_{10} + m_{20}}{m_L + k_1 m_{1P} + m_{20}} \quad .. \quad .. \quad (1)$$

If the burnt first stage is dropped (with zero velocity relative to the remaining vehicle) before satellite altitude is reached, the speed increase due to the second impulse required to attain a circular orbit is

$$\sqrt{r_2 g_2} - v_2 = c_2 \ln \frac{m_L + m_{20}}{m_L + k_2 m_{2P}} \quad .. \quad .. \quad (2)$$

Combination of Equations (1) and (2) gives for $m_L > 0$

$$m_P = \frac{e^{a+b} - 1 - k_1 (e^a - 1)(e^b - 1)}{[1 - k_1 (e^a - 1)][1 - k_2 (e^b - 1)]} m_L \quad .. \quad (3)$$

For "all-fuel" boosters

$$k_1 = k_2 = 0 \quad .. \quad .. \quad .. \quad (4)$$

so that

$$m_P = (e^{a+b} - 1) m_L \quad .. \quad .. \quad (5)$$

and

$$\frac{m_{1P}}{m_{2P}} = \frac{e^a - 1}{e^b - 1} \cdot e^b \quad .. \quad .. \quad (6)$$

In the ensuing analysis the structural masses of the booster rockets will be assumed negligibly small compared with the propellent masses, *i.e.*, Equations (5) and (6) will be assumed applicable.

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III. GEOMETRY OF LAUNCHING AND THE TRAJECTORY OF ASCENT

Let $OXYZ$ be an inertial Cartesian co-ordinate system with origin at Earth's centre, OZ along the axis of Earth's rotation and positive towards the North Pole. Let the OXZ plane contain the point of launch. The OY axis is then parallel to the initial velocity component resulting from Earth's rotation. Let $Cxyz$ be another inertial Cartesian co-ordinate whose origin coincides with the launch point at the instant of launch and which is rotated about OY by angle $\frac{\pi}{2} - \gamma$.

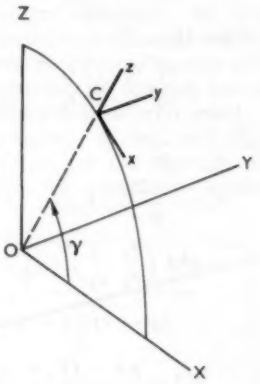

FIG. 1. Co-ordinate system

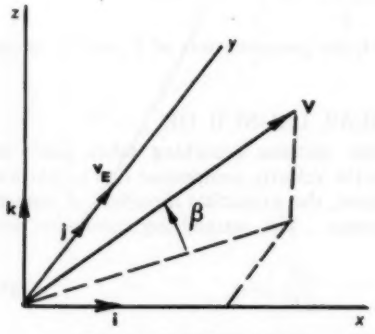

FIG. 2. Launch geometry

Letting $\hat{\mathbf{i}}\,\hat{\mathbf{j}}\,\hat{\mathbf{k}}$ be the unit vector triad of $Cxyz$ we may write

$$\mathbf{v}_E = v_E\hat{\mathbf{j}} \quad .. \quad .. \quad .. \quad (7)$$

where

$$v_E = r_1\,\omega\cos\gamma \quad .. \quad .. \quad .. \quad (8)$$

Also

$$\mathbf{v}_1 = \mathbf{V} + \mathbf{v}_E \quad .. \quad .. \quad .. \quad .. \quad (9)$$
$$= V_x\hat{\mathbf{i}} + (V_y + v_E)\hat{\mathbf{j}} + V_z\hat{\mathbf{k}},$$

where

$$\mathbf{V} = V_x\hat{\mathbf{i}} + V_y\hat{\mathbf{j}} + V_z\hat{\mathbf{k}} \quad .. \quad .. \quad .. \quad (10)$$

In the absence of atmospheric effects the trajectory between first and second impulse is part of a Kepler ellipse in the plane of O and $\mathbf{v}_1$.

From the first integrals of the equations of motion it follows that for horizontal entry into the satellite orbit

$$v_2 = \frac{r_1}{r_2}\left[V_x^2 + (V_y + v_E)^2\right]^{\frac{1}{2}} \quad .. \quad .. \quad (11)$$

and

$$v_1^2 = v_2^2 + 2\mu\left(\frac{1}{r_1} - \frac{1}{r_2}\right) .. \quad .. \quad .. \quad (12)$$

Equations (9), (11) and (12) lead to

$$V_x^2 + (V_y + v_E)^2 = p\,(A - V_z^2) \quad .. \quad .. \quad (13)$$

and

$$v_2 = \frac{r_1}{r_2}\left[p\,(A - V_z^2)\right]^{\frac{1}{2}} \quad .. \quad .. \quad (14)$$

IV. CONDITIONS FOR MINIMUM FUEL CONSUMPTION

From Equation (5) it is seen that the total mass of fuel per unit mass of payload is minimum when $a + b$ is minimum.

In view of Equation (14)

$$F \equiv a + b$$
$$= \frac{\sqrt{V_x^2 + V_y^2 + V_z^2}}{c_1} - \frac{r_1}{r_2}\cdot\frac{\sqrt{p\,(A - V_z^2)}}{c_2} + \frac{\sqrt{r_2 g_2}}{c_2}$$
$$.. \quad (15)$$

It is desired to find the values of V_x, V_y and V_z which minimise F, subject to Equation (13). If V_x and V_z are chosen as independent variables, F possesses a stationary minimum provided

$$\frac{\partial F}{\partial V_x} = 0, \quad \frac{\partial F}{\partial V_z} = 0; \quad (16), (17)$$

$$\frac{\partial^2 F}{\partial V_x^2} > 0, \quad \frac{\partial^2 F}{\partial V_z^2} > 0; \quad .. \quad (18), (19)$$

and

$$\left(\frac{\partial^2 F}{\partial V_x \partial V_z}\right)^2 - \left(\frac{\partial^2 F}{\partial V_x^2}\right)\left(\frac{\partial^2 F}{\partial V_z^2}\right) < 0 \quad .. \quad (20)$$

From Equations (13) and (15) it follows that

$$\frac{\partial F}{\partial V_x} = \frac{v_E V_x}{c_1 V\,(V_y + v_E)} \quad .. \quad .. \quad (21)$$

and

$$\frac{\partial^2 F}{\partial V_x^2} = \frac{v_E}{c_1 V (V_y + v_E)} +$$
$$+\left[\frac{v_E}{c_1 V\,(V_y + v_E)} - \frac{v_E^2}{c_1 V^3}\right]\frac{V_x^2}{(V_y + v_E)^2} \quad .. \quad (22)$$

Thus Equations (16)–(19) are satisfied for

$$V_x = 0 \quad .. \quad .. \quad .. \quad (23)$$

Also

$$\frac{\partial F}{\partial V_z} = CV_z \quad .. \quad .. \quad .. \quad (24)$$

and

$$\frac{\partial^2 F}{\partial V_z^2} = C + DV_z^2 \quad .. \quad .. \quad (25)$$

where

$$C = \frac{v_E - (p-1)\,V_y}{c_1 V\,(V_y + v_E)} + \frac{p}{c_2 v_2}\left(\frac{r_1}{r_2}\right)^2 \quad .. \quad .. \quad (26)$$

and

$$D = \frac{p^2 v_E}{c_1 V (V_y + v_E)^3} + \frac{p^2}{c_2 v_2^3}\left(\frac{r_1}{r_2}\right) - \frac{[v_E - (p-1)\,V_y]^2}{c_1 V^3 (V_y + v_E)^2} \quad .. \quad .. \quad (27)$$

Thus Equations (17) and (19) are fulfilled if

$$\left\{ \begin{array}{ll} V_x = 0 & .. \quad .. \quad .. \quad (28) \\ C > 0, & .. \quad .. \quad .. \quad (29) \end{array} \right.$$

or

$$\left\{ \begin{array}{ll} C = 0 & .. \quad .. \quad .. \quad (30) \\ D > 0, \ (V_z \neq 0). & .. \quad (31) \end{array} \right.$$

Furthermore

$$\frac{\partial^2 F}{\partial V_x \partial V_y} = \left\{ \frac{p v_E}{c_1 V (V_y + v_E)} - \frac{v_E [v_E - (p-1)\,V_y]}{c_1 V^3} \right\} \times \frac{V_x V_z}{(V_y + v_E)^2} \quad .. \quad .. \quad (32)$$

so that in view of Equation (23)

$$\frac{\partial^2 F}{\partial V_x \partial V_z} = 0 \quad .. \quad .. \quad .. \quad (33)$$

and condition (20) is met.

One must now investigate conditions (28)–(31). If Equations (23) and (28) are satisfied, inequality (29) becomes

$$\frac{c_1}{c_2} \cdot \frac{r_1}{r_2} > \left(\frac{r_1}{r_2}\right)^2 - \frac{v_E}{p(\sqrt{pA} - v_E)} \quad .. \quad (34)$$

where the positive root of $(V_y + v_E)^2$ must be selected in solving Equation (13). The question arises whether or not inequality (31) is fulfiled when Equation (30) is imposed and inequality (34) is not met, *i.e.*, when

$$\frac{c_1}{c_2} \cdot \frac{r_1}{r_2} < \left(\frac{r_1}{r_2}\right)^2 - \frac{v_E}{p(\sqrt{pA} - v_E)} \quad .. \quad (35)$$

With Equation (23) imposed, Equation (13) and (30) yield

$$D = \frac{p^2}{c_1 V (V_y + v_E)} \left\{ v_E \left[1 - \left(\frac{r_1}{r_2} \cdot \frac{c_1}{c_2}\right)^2 + \left(\frac{r_1}{r_2} \cdot \frac{c_1}{c_2}\right) \left[V - \left(\frac{r_1}{r_2} \cdot \frac{c_1}{c_2}\right) V_y \right] \right] \right\} \quad .. \quad (36)$$

From the definitions of p and A it follows that

$$v_e^2 = \frac{\mu}{r_1} \leqslant pA \leqslant \frac{2\mu}{r_1} = v_e^2, \quad .. \quad .. \quad .. \quad (37)$$

so that

$$v_E < \sqrt{pA} \quad .. \quad .. \quad .. \quad (38)$$

Then in view of inequality (35)

$$\frac{c_1}{c_2} \leqslant \frac{r_1}{r_2} < 1 \quad .. \quad .. \quad .. \quad (39)$$

Also

$$V_y \leqslant V \quad .. \quad .. \quad .. \quad (40)$$

so that substitution of inequalities (39) and (40) in Equation (36) shows that inequality (31) is fulfilled.

We conclude F possesses a stationary minimum for the range of parameters satisfying inequality (34) as well as for those meeting inequality (35).

In summary, F has a stationary minimum for

Case I:

$$\frac{c_1}{c_2} \cdot \frac{r_1}{r_2} > \left(\frac{r_1}{r_2}\right)^2 - \frac{v_E}{p(\sqrt{pA} - v_E)}, \quad .. \quad (41)$$

if

$$\left. \begin{array}{l} V_x = 0 \\ V_y = \sqrt{pA} - v_E \\ V_z = 0. \end{array} \right\} \quad .. \quad .. \quad (42)$$

Case II:

$$\frac{c_1}{c_2} \cdot \frac{r_1}{r_2} < \left(\frac{r_1}{r_2}\right)^2 - \frac{v_E}{(d\sqrt{pA} - v_E)}, \quad .. \quad .. \quad (43)$$

if

$$\left. \begin{array}{l} V_x = 0 \\ V_y^2 - \dfrac{2v_E}{p-1} V_y + \dfrac{p^2 A \left(\dfrac{r_1}{r_2} \cdot \dfrac{c_1}{c_2}\right)^2 - \left[1 + p\left(\dfrac{r_1}{r_2} \cdot \dfrac{c_1}{c_2}\right)^2\right] v_E^2}{(p-1)\left[1 + p\left(\dfrac{r_1}{r_2} \cdot \dfrac{c_1}{c_2}\right)^2 - p\right]} = 0 \\ V_z^2 = \dfrac{pA - (V_y + v_E)^2}{p}. \end{array} \right\} \quad (44)$$

In Equation (44) the positive roots of V_y and V_z must be chosen.

V. POLAR LAUNCH OR $v_E = 0$

If $v_E = 0$, either because launching takes place at a pole or because the velocity component due to Earth's rotation is neglected, the azimuthal direction of launch is of no consequence. The extremizing conditions are merely

$$\frac{\partial F}{\partial V_z} = 0 \quad .. \quad .. \quad .. \quad (45)$$

and

$$\frac{\partial^2 F}{\partial V_z^2} > 0 \quad .. \quad .. \quad .. \quad (46)$$

Then F has a stationary minimum for

Case I:

$$\frac{c_1}{c_2} > \frac{r_1}{r_2} \quad .. \quad .. \quad .. \quad (47)$$

if

$$\left. \begin{array}{l} V_y = \sqrt{pA} \\ V_z = 0 \end{array} \right\} \quad .. \quad .. \quad (48)$$

Case II:

$$\frac{c_1}{c_2} < \frac{r_1}{r_2} \quad .. \quad .. \quad .. \quad (49)$$

if

$$c_1 v_1 = c_2 v_2 \quad .. \quad .. \quad .. \quad (50)$$

i.e.,

$$\left.\begin{aligned} V_y^2 &= \frac{pA}{1+p\left[\left(\frac{r_1}{r_2}\cdot\frac{c_2}{c_1}\right)^2-1\right]} \\ V_z^2 &= \frac{pA-V_y^2}{p} \end{aligned}\right\} \quad \ldots (51)$$

Here again the positive roots of horizontal and vertical components V_y and V_z must be selected.

It is concluded that for $v_E \neq 0$ launching must take place in the Easterly direction. The ratio of specific impulses c_1/c_2 governs the launch angle β and the staging ratio m_{1P}/m_{2P}. When c_1/c_2 falls below a critical value, horizontal launch is no longer optimum. As c_1/c_2 decreases, *i.e.*, the first stage decreases in efficiency relative to the second stage, β_{OPT} increases. From Equation (14) it can be seen that this corresponds to utilising less of the first impulse for the establishment of orbit speed.

Fig. 3–5 present plots of m_P/m_L, m_{1P}/m_{2P} and β_{OPT}, respectively, as functions of c_1/c_2 for the case $v_E = 0$, $c_1 = 10^4$ ft./sec., and $r_1/r_2 = 0{\cdot}8$ (1000-mile orbit).

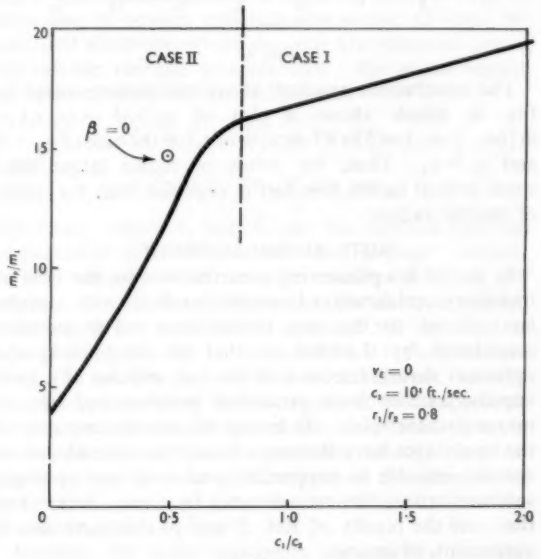

FIG. 3.

Fig. 3 shows the increasing fuel requirement with decreasing efficiency. The transition between Case I ($\beta_{OPT} = 0$) and Case II ($\beta_{OPT} > 0$) is smooth, *i.e.*, the slope of the curve has the same value on either side of the critical point (here $r_1/r_2 = c_1/c_2 = 0{\cdot}8$). Fig. 4 is of interest since it illustrates a marked difference in behaviour of m_{1P}/m_{2P} in the two regions I and II. Fig. 5 demonstrates the rapid increase of β_{OPT} in region II. To show the effect of launching at a non-optimum angle the value of m_P/m_L is plotted on Fig. 3 for $\beta = 0$ ($\beta_{OPT} \cong 51$ deg.) and $c_1/c_2 = 0{\cdot}5$.

The vehaviour of m_P/m_L, β_{OPT} and m_{1P}/m_{2P} for $v_E \neq 0$ shows only minor differences from that of the case $v_E = 0$. Of course, m_P/m_L is somewhat smaller

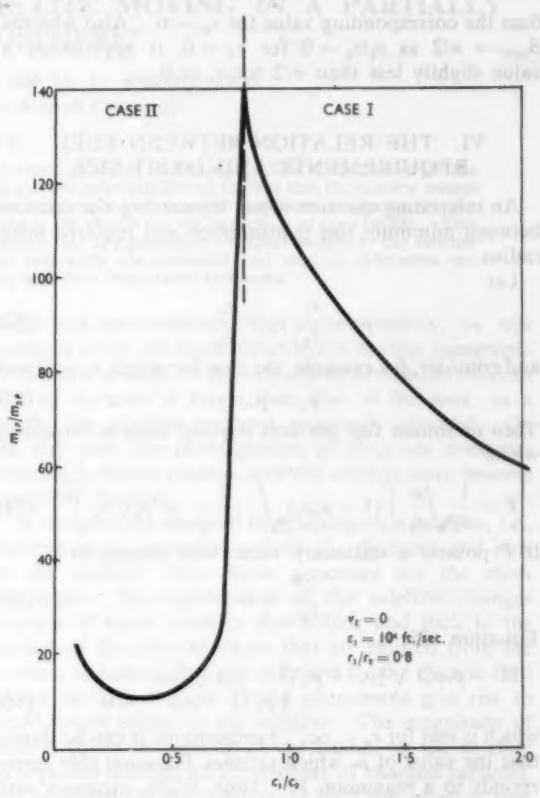

FIG. 4.

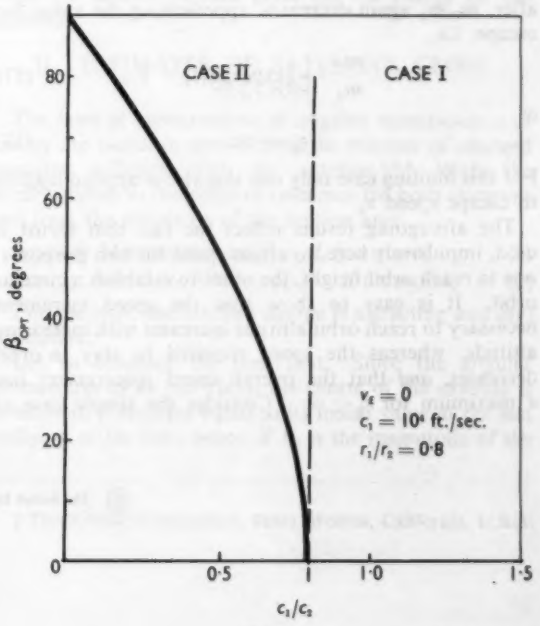

FIG. 5

than the corresponding value for $v_E = 0$. Also whereas $\beta_{OPT} \to \pi/2$ as $c_1/c_2 \to 0$ for $v_E = 0$, it approaches a value slightly less than $\pi/2$ for $v_E \neq 0$.

VI. THE RELATION BETWEEN FUEL REQUIREMENTS AND ORBIT SIZE

An interesting question arises concerning the relation between minimum fuel consumption and required orbit radius.

Let

$$\rho_r = \frac{r_1}{r_2}, \quad \rho_c = \frac{c_1}{c_2} \quad .. \quad .. \quad .. \quad (52)$$

and consider, for example, the case for which $v_E = 0$ and

$$\rho_c > \rho_r \quad .. \quad .. \quad .. \quad (53)$$

Then minimum fuel per unit payload mass is consumed when

$$F = \frac{1}{c_1}\sqrt{\frac{\mu}{r_1}}\left[(1 - \rho_r\rho_c)\sqrt{\frac{2}{1+\rho_r}} + \rho_c\sqrt{\rho_r}\right] \quad (54)$$

If F possess a stationary value with respect to ρ_r,

$$\frac{\partial F}{\partial \rho_r} = 0 \quad .. \quad .. \quad .. \quad (55)$$

Equation (55) is

$$(1 - \rho_r\rho_c)\sqrt{\tfrac{1}{2}\rho_r} + \rho_c(1+\rho_r)\sqrt{2\rho_r} - \tfrac{1}{2}\rho_c(1+\rho_r)^{3/2} = 0 \quad .. \quad (56)$$

which is met for $r_2 < \infty$. Furthermore, it can be shown that the value of ρ_r which satisfies Equation (56) corresponds to a maximum F. Thus, m_P/m_L increases with increasing r_2 until r_2 reaches a critical value. Thereafter, m_P/m_L again decreases approaching the value for escape, *i.e.*,

$$\frac{m_P}{m_L} \to [\exp(v_E/c_1)] - 1 \quad .. \quad .. \quad (57)$$

as

$$r_2 \to \infty \quad .. \quad .. \quad .. \quad (58)$$

For this limiting case only one impulse is applied leading to escape speed v_e.

The aforegoing results reflect the fact that thrust is used, impulsively here, to attain speed for two purposes: one to reach orbit height, the other to establish a circular orbit. It is easy to show that the speed increment necessary to reach orbit altitude increases with increasing altitude, whereas the speed required to stay in orbit decreases, *and* that the overall speed requirement has a maximum for $r_2 < \infty$. Consider the simple case of unit mass projected vertically and required to coast to height r_2. The initial speed must be

$$v_s\sqrt{2(1-\rho_r)} \quad .. \quad .. \quad (59)$$

To establish unit mass in a circular orbit at r_2, it must be boosted to a speed

$$v_s\sqrt{\rho_r} \quad .. \quad .. \quad .. \quad (60)$$

that is, the overall speed requirements is given by

$$\frac{\Delta v}{v_s} = \sqrt{2(1-\rho_r)} + \sqrt{\rho_r} \quad .. \quad (61)$$

For this simple model $\Delta v/v_s$ has a maximum when

$$\rho_r = \tfrac{3}{4}, (r_2 \cong 6000 \text{ miles}) \quad .. \quad .. \quad (62)$$

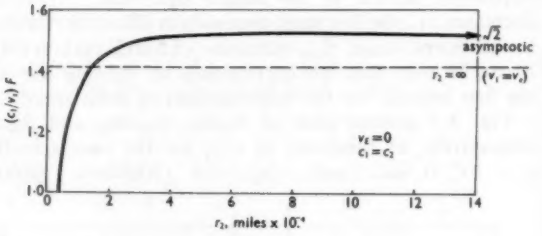

FIG. 6

The conclusions reached above are demonstrated in Fig. 6, which shows a plot of $(c_1/v_s)F = (c_1/v_s) \times \ln[(m_L + m_P)/m_L]$ as a function of r_2 for the case of $v_E = 0$ and $c_1 = c_2$. Thus, for orbits of radius larger than some critical radius less fuel is required than for orbits of smaller radius.

NOTE ADDED IN PROOF

In one of his pioneering contributions to the field of trajectory optimization Lawden[5] has dealt with a problem related to the one treated here. The question considered by Lawden is that of determining the optimum thrust direction of the first impulse of a two-impulse transfer from prescribed position and velocity into a circular orbit. In letting the specific impulses of the two stages have the same value, the dependence on specific impulse is suppressed and only one optimum solution arises, the one denoted by Case I here. For that case the results of Ref. 5 and of this note are in agreement, of course.

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ON THE DRAG OF A SPHERICAL SATELLITE MOVING IN A PARTIALLY IONIZED ATMOSPHERE*

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(Communication from Hughes Aircraft Company)

ABSTRACT

The drag on a spherical Earth satellite due to neutral and charged particles is discussed. The temperatures of the electrons and positive ions are assumed to be approximately equal and for most satellites it follows that the satellite sweeps out ions and neutral particles only along its direction of motion but is bombarded from all directions by electrons. An important parameter which determines the drag of charged particles is the charge (or the potential) of the satellite. This charge is determined for two different cases by the boundary condition that at equilibrium the total current to the satellite is zero. Competitive processes which would charge the satellite oppositely are discussed and used to determine the potential of the satellite. "Distant" collisions are discussed briefly and their importance estimated.

I. INTRODUCTION

At altitudes of 500 km. and greater, the number of charged particles per unit volume may approach that of the neutral particles; hence, at these altitudes, the Coulomb attraction or repulsion of the charged particles must be considered in determining the total atmospheric drag acting on a satellite.

Consider as the model of the atmosphere, through which the satellite passes, a partially ionized medium consisting of oxygen and nitrogen atoms, O^+ and N^+ ions, and electrons, where the ions and electrons are at comparable thermal temperatures. The mean square velocities of the electrons and ions are

$$V_e \cong 5 \times 10^7 \sqrt{\theta_e} \text{ cm./sec.}$$

and

$$V_i \cong 2 \times 10^5 \sqrt{\theta_i} \text{ cm./sec.}$$

repectively, where θ_e and θ_i are the electron and ion temperatures in electron-volts. An "average" velocity for the majority of the current satellites is $V_s \cong 10^6$ cm./sec. Recent data indicate that the electron and ion temperatures are comparable at about 500 km., and as a guide $\theta_e \cong \theta_i$ will be taken to be 0·1 electron-volt. Thus, the satellite is travelling at a subsonic velocity compared with that of the electrons and at a supersonic velocity compared with that of the ions; to an observer located on the satellite, the randomly moving electrons appear to bombard the satellite from all directions while the satellite appears to sweep out ions along its direction of motion only.

Actually, the latter picture is not entirely correct.[1] An important property of a plasma is the ability of electrostatic forces to enforce a state of charge neutrality. In the wake behind the satellite there is a deficiency of ions, and consequently the electron concentration in the wake will also be less than it is several diameters from the surface of the satellite. An estimate of the electron density in the wake will be given in the Appendix. In order not to complicate the picture unduly, we will continue to use the model described in the last paragraph.

Initially, because of this velocity difference the incident flux of electrons is larger than that of the ions; as a result, the satellite becomes negatively charged. On the day side, the photoejection of electrons competes with the collision process, and the satellite may become positively charged.

In determining the total drag acting on a satellite, *i.e.*, the transfer of momentum from the electrons and ions to the satellite, three basic processes are the most important. The momentum of the satellite changes because of those particles that collide and stick to the surface of the satellite, those that are emitted from the surface, and those that are deflected by the electric field of the satellite. These diverse phenomena give rise to small forces acting on the satellite. The magnitude of each is chiefly a function of the charge on the satellite as it passes through an atmosphere of charged particles. A knowledge of the number of particles of each sign from the satellite surface gives the net charge on the satellite.

II. ESTIMATES OF SATELLITE CROSS SECTION

The laws of conservation of angular momentum and energy are useful in determining the number of charged particles colliding with the satellite.[2,3,4] With the satellite taken as the point of reference for both electrons and ions, the constants of the motion are:

$$\text{Angular Momentum: } mr^2\dot{\theta} = L \text{ (constant)} \quad . . \quad (1)$$

$$\text{Energy: } \tfrac{1}{2}m(\dot{r}^2 + r^2\dot{\theta}^2) - e\phi(r) = E \text{ (constant)} \quad (2)$$

For the ions, the satellite charge is attracting and $\phi(r)$ is positive.

Let us consider the ions first. Since the angular momentum of an ion about the centre of the satellite is conserved, it remains equal to its initial value at the last collision of the ion; hence, if V_s is the magnitude of the

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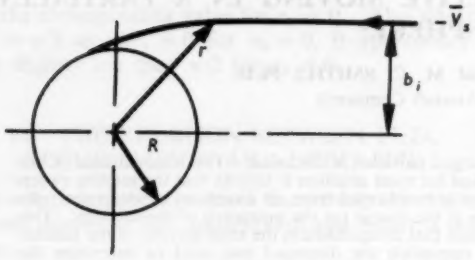

FIG. 1

ion velocity relative to that of the satellite after the last collision before it encounters the satellite (see Fig. 1),

$$L = mV_s b_i = mr^2\dot{\theta} = mb_i\sqrt{2E/m} \quad .. \quad (3)$$

where E is the kinetic energy of the ion relative to that of the satellite (at a distant point, the potential energy is negligible). Solving for $\dot{\theta}$ in (3) and substituting in (2) gives

$$E = \frac{m\dot{r}^2}{2} + \frac{Eb_i^2}{r^2} - e\phi(r) \quad .. \quad .. \quad (4)$$

The further assumption is made that the only ions which contribute to the drag are those which actually strike the satellite (we assume that no sheath is formed). Now $\dot{r} = 0$ when $r = R$, and (4) yields

$$E\left(\frac{1 - b_i^2}{R^2}\right) = e\phi(R) \; .. \quad .. \quad (5)$$

Solving (5) for b_i, the effective impact parameter for the ions, we get

$$b_i = R\sqrt{1 + \frac{e\phi(R)}{E}} \quad .. \quad (6)$$

Equation (6) can be interpreted as meaning that a charged spherical satellite collecting positive ions has an effective area greater than that of the projected area of the satellite by the factor

$$\left[1 + \frac{e\phi(R)}{E}\right] \quad .. \quad .. \quad (6a)$$

Similarly, it can be shown that the collision parameter for electrons b_e is less than the radius of the satellite by the factor

$$b_e = \sqrt{1 - \frac{e\phi(R)}{E}} \quad .. \quad .. \quad (6b)$$

If n_i is the ion particle density, $\bar{V}_s$, the mean velocity of the satellite relative to that of the ions, is approximately equal to the satellite velocity V_s (since $V_s \gg V_i$), and if A_i is the effective collection area for the ions, the ion current is

$$I_i = en_i\bar{V}_s A_i \quad .. \quad .. \quad .. \quad (7)$$

By use of (6), (7) becomes

$$I_i = en_i\bar{V}_s\pi R^2\left[1 + \frac{e\phi(R)}{E}\right] \quad .. \quad (8)$$

Since the electron velocity is at least an order of magnitude larger than that of the satellite, the electrons will collide with the satellite from all directions (see the Appendix for a discussion of the validity of this assumption). If all directions are assessed as equally likely and if the electrons have no mass motion with respect to the satellite, then the chance that the direction of the velocity of an electron lies within a solid angle is exactly proportional to the magnitude of the solid angle. The mean velocity of an electron with its direction lying within a small solid angle is*

$$\int_{V_0}^{\infty} \frac{\underline{c}^3}{\alpha^3\pi^{3/2}} \exp(-\underline{c}^2/\alpha^2)\, d\underline{c}\, d\omega \quad .. \quad (9)$$

where $\alpha^2 = 2KT_e/m_e$, $V_0 = \sqrt{2e\phi(R)/m}$, and c is the resultant particle velocity. The mean current density in the direction of solid angle $d\omega$ is

$$\int_{V_0}^{\infty} \frac{en_e\underline{c}^3}{\alpha^3\pi^{3/2}} \exp(-\underline{c}^2/\alpha^2)\, d\underline{c}\, d\omega \quad .. \quad (10)$$

where n_e is the electron density.

The amount of current striking the satellite in any direction is equal to that striking a circle of radius b_e. By virtue of Equation (6*b*)[5]

$$I_e = -\frac{en_e\,\pi\,R^2}{\alpha^3\,\pi^{3/2}} \times$$

$$\times \int_0^{4\pi}\int_{V_0}^{\infty} \underline{c}^3\left(1 - \frac{2e\phi(R)}{m\underline{c}^2}\right)\exp(-\underline{c}^2/\alpha^2)\, d\underline{c}\, d\omega \quad (11)$$

where only the electrons with a velocity V_0 or greater can penetrate the potential barrier and hit the satellite. Integrating (11), we obtain

$$I_e = \frac{4en_e\pi R^2}{\alpha^3\pi^{1/2}}\left[\frac{\alpha^2}{2}\exp(-V_0^2/\alpha^2)(V_0^2 + \alpha^2) - \right.$$

$$\left. - \frac{2e\phi(R)\alpha^2}{2m_e}\exp(-V_0^2/\alpha^2)\right] \quad .. \quad (12)$$

which reduces to

$$I_e = -2en_e\sqrt{\pi}R^2\,\alpha\exp(-V_0^2/\alpha^2) \quad .. \quad (13)$$

III. SATELLITE POTENTIAL

To obtain the equilibrium potential of the satellite, the sum of the electron current and ion current is set equal to zero:

$$I_i + I_e = 0 \quad .. \quad .. \quad (14)$$

* An equilibrium distribution is not strictly accurate since energy is being supplied to the upper atmosphere in the form of ultraviolet radiation, etc.

In writing (14), we assume that the electrons and ions that strike the satellite combine to form neutral particles and that the exchange of momentum that occurs when neutral particles leave the satellite is very small compared with the exchange of momentum that results when they hit the satellite. From (8) and (13)

$$\overline{V_e}\left(1+\frac{e\phi(R)}{E_i}\right)-\frac{2\alpha}{\sqrt{\pi}}\exp[-e\phi(R)/KT_e]=0 \quad (14a)$$

Solving (14*a*) for the equilibrium potential gives

$$\phi(R)=\frac{KT_e}{e}\ln\frac{\alpha}{V_e}-\frac{KT_e}{e}\ln\sqrt{\frac{\pi}{4}}\left[1+\frac{e\phi(R)}{E_i}\right] \quad (15)$$

IV. PHOTOELECTRIC EFFECT

On the day side of the satellite orbit, the solar ultraviolet and X-ray photons liberate electrons from the satellite surface which modify the charge on the satellite due to collisions with electrons and ions. The sign of the charge and the potential of the satellite depend on the relative importance of the competitive processes charging the satellite.

The power dS (ergs/cm.^{2}sec.) incident upon a normal surface of area da flowing into a solid angle $d\omega$ in the wavelength range λ and $\lambda+d\lambda$ is given by

$$dS=E_\lambda\,d\lambda\,d\omega \quad .. \quad .. \quad .. \quad (16)$$

where E_λ (ergs/cm.^{3}sec.) is the intensity of radiation of wavelength λ. The intensity E_λ for temperature T is given by Planck's Law as

$$E_\lambda=\frac{h\nu^5}{c^3\,[\exp(h\nu/KT)-1]} \quad .. \quad (17)$$

For $KT\ll h\nu$, (17) becomes

$$E^\lambda\cong\frac{h\nu^5}{c^3}\exp(-h\nu/KT) \quad .. \quad .. \quad (18)$$

where h is Planck's constant and $c=\lambda\nu$.

If dn is the number of quanta of energy $h\nu$ per cm.^{2}/sec. at any point in space, then

$$dS=h\nu\,dn \quad .. \quad .. \quad .. \quad (19)$$

and from (19), (18), and (16),

$$dn=\frac{1}{c^2}\exp\left(-\frac{h\nu}{KT_s}\right)\nu^2\,d\nu\,d\omega \quad .. \quad (20)$$

where T_s is the temperature of an equivalent black-body sun.

If μ is the absorption coefficient and if the absorption is identical to the ionization, the rate of photoionization is found by integrating (20) between $\nu_0=\dfrac{e\phi(R)}{h}+\dfrac{W}{h}$ and $\nu=\infty$, where W is the work function of the surface of the satellite.

The amount of current leaving that half of the surface of the satellite illuminated by the sun is

$$-\frac{2\pi R^2e\bar{\mu}}{c^2}\int_0^{2\pi}\int_{\nu_0}^{\infty}\exp\left(-\frac{h\nu}{KT_s}\right)\nu^2\,d\nu\,d\omega \quad .. \quad (21)$$

where $\bar{\mu}$ is the average absorption coefficient.

Integrating (21) by parts gives

$$I_{ph}=\frac{-4\pi^2R^2e\bar{\mu}}{c^2}\left(\frac{KT_s}{h}\right)^3\exp(-y)(y^2+2y+2) \quad (22)$$

where

$$y=\frac{e\phi(R)+W}{KT_s}$$

By requiring that $I_i+I_e+I_{ph}=0$, we have from (8), (13) and (22), the equation that the equilibrium potential satisfies:

$$n_i\overline{V_i}\left[1+\frac{e\phi(R)}{E_i}\right]-\frac{2n_e}{\sqrt{\pi}}\alpha\exp\left[-\frac{e\phi(R)}{KT_e}\right]-$$
$$-\frac{4\pi\bar{\mu}}{c^2}\left(\frac{KT_s}{h}\right)^3\exp(-y).\,(y^2+2y+2)=0 \quad (23)$$

Equation (23) may be simplified to

$$\phi(R)=\frac{KT_e}{e}\left\{\ln\frac{\alpha}{V_e}-\ln\sqrt{\frac{\pi}{4}}\frac{n_i}{n_e}\left[1+\frac{e\phi(R)}{E_i}\right]-\right.$$
$$\left.-\ln\frac{\sqrt{4\pi^3\bar{\mu}}}{c^2\alpha n_e}\left(\frac{KT_s}{h}\right)^3.\exp(-y)\,(y^2+2y+2)\right\} \quad (24)$$

If representative numbers are substituted in (24), the first term on the right side dominates the others.[6] The Russian measurements of potential of satellite 1958 *gamma* with respect to the surrounding neutral plasma appear to substantiate the conclusion that the photoelectric effect is small. See Table I for the meagre data now available.[7]

TABLE I

Altitude, km.	Potential Measured, Volts	
	Day	Night
795	−6·4	0 ± 1
242	−2	0 ± 1

If it is assumed that the photoelectric effect is small, (24) reduces to

$$\phi(R)\cong\frac{KT_e}{e}\cdot\ln\frac{\alpha}{V_e} \quad .. \quad .. \quad (25)$$

On the basis of the Russian data, computed electron temperatures are given by (25) as of the order of 15×10^3 °K. to $7{\cdot}5\times10^3$ °K. for altitudes of 795 km. and 242 km., respectively.

V. COULOMB DRAG RESULTING FROM COLLISIONS

Assume that the charged ions stick to the surface of the satellite; the number colliding per second is $\pi n_iV_ib_i^2$.

Hence, the rate of momentum transfer is

$$\pi n_i m_i V_s^2 b_i^2 \quad .. \quad .. \quad .. \quad (26)$$

where $m_i V_s$ is the momentum of an ion. From Equation (6), (26) becomes

$$\pi m_i n_i V_s^2 R^2 \left[1 + \frac{e\phi(R)}{E}\right] \quad .. \quad (27)$$

Likewise, the drag due to the neutral particles is

$$\pi m_i n V_s^2 R^2 \quad .. \quad .. \quad .. \quad (28)$$

where $m_i \cong m$.

The ratio of (27) to (28) is

$$\frac{n_i}{n}\left[1 + \frac{e\phi(R)}{E}\right] \quad .. \quad .. \quad (29)$$

VI. EFFECTIVE CROSS SECTION

The increase of collection area of positive ions given by (29) is the upper limit of the current collected at the given satellite potential. A number of other conditions must be satisfied if this upper limit is to be realized. Under certain conditions the electric field of the satellite will be confined to a sheath surrounding the satellite. In this case, the increase in the number of positive ions collected will be much less than predicted by (29). When a sheath is present, the effective size of the satellite is increased as the extent of the sheath. When the distribution of the electric field is only in part confined to the sheath and the remainder penetrates into the plasma, a larger effective cross section is expected.

Let b_{max} be the maximum collision parameter that an ion may have if it is to penetrate to a radius r.

$$b_{max}^2 = r^2\left[1 + \frac{e\phi(r)}{E}\right] \quad .. \quad .. \quad (30)$$

Two conditions are necessary[4] for a particle to reach a given r; b must be less than $b_{max}\,(r)$ for that value of r, and b must be less than $h_{max}\,(r)$ for all greater values of r. Thus, for (30) to be correct,

$$\frac{db_{max}}{dr} = \frac{r}{2h_{max}}\left\{2\left[1 + \frac{e\phi(r)}{E}\right] + \frac{re}{E}\cdot\frac{d\phi(r)}{dr}\right\} > 0 \quad (31)$$

for $r \geqslant R$.

When $\left.\frac{db_{max}}{dr}\right|_{r_0} < 0$, then all particles which reach r_0 can also reach a radius less than r_0 since h_{max} is increasing with decreasing r. Here all the particles that penetrate to the distance r_0 are captured by the satellite. An intermediate situation arises when at r_1, $db_{max}/dr = 0$ and $db/dr < 0$ for $r < r_1$, and $db/dr > 0$ for $r > r_1$. The particles that reach r_1 with with $b \leqslant b_{max}\,(r_1)$ and have $b < b_{max}\,(r)$ for all $r > r_1$ are captured. The effective radius is taken here as $b(r_1)$.

In order to study that potential distribution in the neighbourhood of the satellite, Poisson's equation

$$\frac{1}{r^2}\cdot\frac{d}{dr}\left[r^2\frac{d\phi(r)}{dr}\right] = 4\pi(n_e - n_i)e \ldots \quad (32)$$

must be solved, where, as previously, the electrons are assumed to be in thermal equilibrium:

$$n_e = n_0 \exp\left[-\frac{e\phi(r)}{KT_e}\right] \quad .. \quad (33)$$

It is necessary to find a relation between n_i and $\phi(r)$ before (32) can be solved. Because of the small potentials and distances involved, the ion density in the neighbourhood of the satellite is assumed to be a constant; *i.e.*, the increase in ion current due to the negative potential of the satellite is neglected. Other assumptions are: (*a*) Negligible ionization occurs in the neighourhood of the satellite; (*b*) Ions are charged singly, and (*c*) $n_e = n_i = n_0$ in the undisturbed plasma. Solution of (32) is carried out for the two satellite potentials given in Table I.

Fig. 2 illustrates the decrease in the potential with increasing distance from the satellite. In each case of

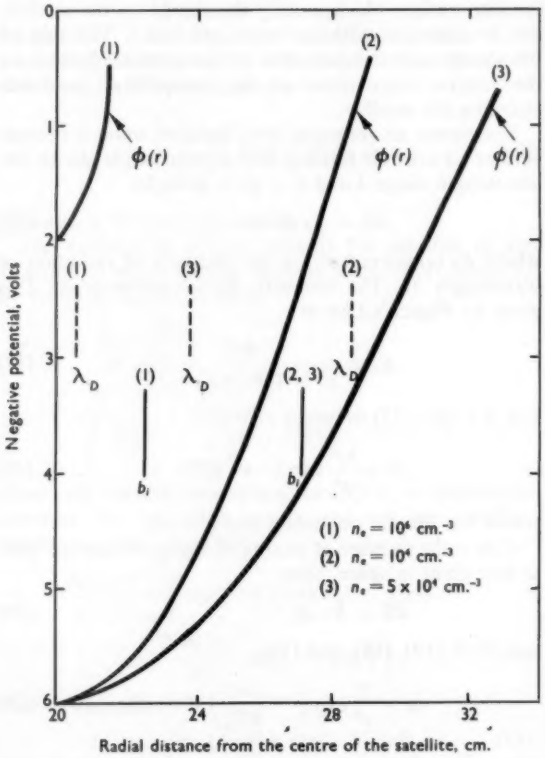

FIG. 2

initial potential, (31) is positive for increasing r; hence, the effective satellite radius is given by (6). Both Equation (6) and the Debye shielding distance are indicated in Fig. 2. The agreement between the effective satellite radius as given by (6) and the Debye length

$$\lambda_D = [KT_e/(4\pi n_e e^2)]^{1/2} = 6{\cdot}9\sqrt{T_e/n_e}\ \text{cm.}$$
$$= 750\sqrt{\theta_e/n_e}\ \text{cm.} \quad .. \quad (33a)$$

improves as the altitude increases. This is to be expected since in (6) the particle interactions are neglected.

At the lower altitudes (250 km.) the drag arising from the relatively denser neutral particles will dominate. However, at altitudes of 800 km., the charged particle density approaches that of the neutral particles, and the ratio of charged particle drag to neutral particle drag given by (29) becomes 2.2 n_i/n.

VII. DYNAMIC FRICTION RESULTING FROM NEAR "COLLISIONS"

In the region in which the electric field of the charged satellite penetrates into the plasma (see Fig. 2), the motion of the charged particles is modified by the Coulomb interaction with the satellite field. An analysis of the energy loss of the satellite in such encounters makes use of the Bohr formulation of the similar problem of ionization by electromagnetic interactions.[8]

Consider, for the present, one ion of mass m_i at a distance l from the path of the oncoming satellite of charge Ze and velocity V_s. The component of momentum acquired by the ion during the "collision" parallel to the path of the satellite is by symmetry zero. This assumes that the ion moves very little during the "collision." The impulse perpendicular to the path is given by

$$\int eE_1 \, dt \qquad .. \qquad .. \qquad .. \qquad (34)$$

where E_1 is the perpendicular component (to the satellite path) of field intensity at the ion due to the charge Ze of the satellite.

From Gauss' theorem, the flux through a surface enclosing the charge Ze is

$$\int \overline{E}.\,\overline{dS} = 4\pi Ze \qquad .. \qquad .. \qquad (35)$$

The flux passing through a cylindrical surface parallel to the path of radius l is

$$\int_{-\infty}^{\infty} 2\pi l E_1 \, dx = 4\pi Ze \qquad .. \qquad (36)$$

Now

$$\int E_1(t)\, dt = \int E_1(x) \frac{dx}{V_s} = \frac{2Ze}{V_s l} \qquad .. \qquad (37)$$

From (34), the momentum acquired by the ion is

$$P = \frac{2Ze^2}{V_s l} \qquad .. \qquad .. \qquad .. \qquad (38)$$

Hence, the energy acquired by the ion is

$$\frac{p^2}{2m_i} = \frac{2Z^2e^4}{m_i V_s^2 l^2} \qquad .. \qquad .. \qquad (39)$$

The number of collisions per centimetre in the range l to $l + dl$ is equal to the number of ions per centimetre in the shell bounded by the cylinders of radius l and $l + dl$. The energy lost by the satellite per centimetre to such ions is

$$dE(l) = \frac{4\pi Z^2e^4n_i}{m_i V_s^2 l} \cdot dl \qquad .. \qquad (40)$$

Thus the total force acting on the satellite due to the energy loss per centimetre is obtained by integrating (40) between the limits (b, b_1):

$$\frac{\Delta E}{\Delta x} = \frac{4\pi Z^2e^4n_i}{m_i V_s^2} \ln \frac{b_1}{b} \qquad .. \qquad (41)$$

where b is the effective radius of the satellite and b_1 is a radius somewhat greater than the effective impact parameter of the ions in (6).

A more elaborate derivation of this result has been carried out for low-density gases at low temperatures by Chandrasekhar and Spitzer.[9,10] For a spherical satellite $Ze = b\,\phi(b)$; hence, (41) may be written as

$$\frac{\Delta E}{\Delta x} = 2\pi b^2 \frac{[\phi(b)e]^2}{(\frac{1}{2}m_i V_s^2)^2} n_i \ln \frac{b_1}{b} \qquad .. \qquad (42)$$

The ratio of dynamic friction to neutral particle drag is then

$$\frac{2b^2}{R^2} \frac{[\phi(b)e]}{(\frac{1}{2}m_i V_s^2)^2} \frac{n_i}{n} \ln \frac{b_1}{b} \qquad .. \qquad (43)$$

For an altitude of 800 km., (43) becomes

$$\sim 0{\cdot}4 \frac{n_i}{n} \ln \frac{b_1}{b} \qquad .. \qquad .. \qquad (44)$$

For large spheres, $b \sim b_1$; hence, from (44) the dynamic friction becomes small.

VIII. CONCLUSIONS

For altitudes of the order of 800 km., the free-particle model appears to be appropriate in calculating the increase in drag due to ions that stick to the surface of the satellite and those that pass near the satellite. At a lower altitude, 250 km., the much greater density of neutral particles completely overshadows the effects of Coulomb interactions. For altitudes between 250 km. and 800 km., the theory should be useful in giving approximate magnitudes of the Coulomb interactions.

Surface interactions, particles leaving the surface, reflection of impinging particles, and the effect of the Earth's magnetic field have been neglected. A study of these effects should be included in order to complete the analysis.

APPENDIX

In calculating the flux of electrons bombarding the satellite surface, Equation (13), we assumed that because the average velocity of the electrons is at least one order of magnitude greater than that of the satellite, the satellite is bombarded by electrons equally from all directions. In reality, because of the basic property of the charge neutrality of a plasma, this assumption is somewhat questionable since the satellite is travelling at a supersonic velocity through the plasma with respect to the velocity

of the ions. Consequently a wake occurs behind the satellite in which there is a deficiency of ions, and because the ions hold the electrons within a Debye length of themselves, the electron concentration in the wake is also less than it is several diameters from the satellite surface. The wake behind the satellite will be assumed to be circular in cross section, and it will extend back a distance of the order of $MV_s^2/[eR\phi(R)]$ or the mean free path, whichever is smaller. We will assume that the mean free path is the larger of the latter two quantities and will calculate the electron density in the wake.[11]

To find the electron distribution, we must solve Poisson's equation

$$\nabla^2\phi(\bar{r}) = 4\pi(\rho_- - \rho_+) \quad .. \quad .. \quad \text{(A. 1)}$$

where ρ_- and ρ_+ are the electron and ion charge density, respectively, and $\rho_- \geqslant 0$. ρ_+ is a step function having the values:

$$\begin{aligned}\rho_+ &= 0, \text{ in the wake}\\ &= \rho_0, \text{ the ambient charge density outside the wake} \quad .. \quad .. \quad .. \quad .. \quad \text{(A. 2)}\end{aligned}$$

In a highly ionized plasma, the relaxation time for the electron gas is approximately[10]

$$t_0 = \frac{\theta_e^{3/2}}{n_e} \times 10^6 \text{ sec.} \quad .. \quad \text{(A. 3)}$$

The value of t_0 is assumed to be so short that the electrons are at equilibrium and obey Boltzmann's distribution

$$\rho_- = \rho_0 \exp[e\phi(\bar{r})/kT_e] \quad .. \quad .. \quad .. \quad \text{(A. 4)}$$

Putting (A. 2) and (A. 4) into (A. 1) and staying sufficiently far away from the satellite so that $e\phi(\bar{r})/kT_e$ is much less than unity, we get

$$\nabla^2\phi(\bar{r}) - \lambda_D^{-2}\phi(\bar{r}) = 4\pi\rho_0, \quad \bar{r} \text{ in the wake} \quad .. \quad \text{(A. 5)}$$

where $\lambda_D^2 = kT_e/(4\pi e\rho_0)$. The solution of (A. 5) is well known from the theory of Green's function:

$$\phi(\bar{r}) = -\rho_0 \int' \frac{1}{|\bar{r}-\bar{r}'|} \exp(-|r-r'|/\lambda_D)\, dV' \quad \text{(A. 6)}$$

In (A. 6), $\int'$ means that the integration is performed over the volume of the wake. Because λ_D is small in most cases compared with the dimensions of the wake, we can approximate (A. 6) accurately by integrating only over points $\bar{r}$, such that

$$\alpha = \alpha(\bar{r}, \bar{r}') = |\bar{r}-\bar{r}'| \leqslant \lambda_D \quad .. \quad .. \quad \text{(A. 7)}$$

Thus, to a high degree of approximation, the edge of the wake can be considered to be a plane. For points at a distance Z within the wake, (A. 6) yields

$$\begin{aligned}\phi_{in}(Z) = -\pi\rho_0 \Bigg[&\int_0^{\pi/2} \sin\theta'\, d\theta' \int_0^{Z\sec\theta'} \alpha \exp(-\alpha/\lambda_D)\, d\alpha +\\ &+ \int_{\pi/2}^{\pi} \sin\theta'\, d\theta' \int_0^{\infty} \alpha \exp(-\alpha/\lambda_D)\, d\alpha \Bigg]\end{aligned}$$

$$= -4\pi\rho_0\lambda_D^2\left[1 - \tfrac{1}{2}\int_0^1 \left(1 + \frac{Z}{\lambda_D s}\right)\exp(-Z/\lambda_D s)\, ds\right]$$

$$= -4\pi\rho_0\lambda_D^2[1 - \tfrac{1}{2}\exp(-Z/\lambda_D)] \quad .. \quad .. \quad \text{(A. 8)}$$

The electron density in the wake, $\rho_{-in}(Z)$, is then

$$\rho_{-in}(Z) = \frac{\rho_0}{2}\exp(-Z/\lambda_D) \quad .. \quad .. \quad .. \quad \text{(A. 9)}$$

The electron density outside the wake can be obtained similarly by remembering that the surface of the wake $\rho_{-in}(0) = \rho_{-out}(0)$ and that far from the wake $\rho_{-out}(\infty) = \rho_0$. Thus

$$\rho_{-out}(Z) = \rho_0[1 - \tfrac{1}{2}\exp(-Z/\lambda_D)] \quad .. \quad \text{(A. 10)}$$

Equations (A. 9) and (A. 10) show that our assumption that the satellite is bombarded equally from all directions is incorrect. A cylindrical wake exists behind the satellite, and the electron density inside and outside the wake is given by (A. 9) and (A. 10). Equation (13), the expression for the electron current to the satellite, is only approximate, and for a better expression the dependence of n_e on θ and the distance within the wake must be taken into account. When this is done, the definite integrals that result are intractable, and approximations must be made in evaluating them. The expense of performing the integration numerically would not be worthwhile because of the small amount of reliable information now available on the physical properties of the atmosphere at great heights. As a compromise, the electron current I_e in (13) should be divided by two. Physically, we are then assuming that the electrons bombard only the front half of the satellite.

LIST OF SYMBOLS

A_e, A_i	electron, ion effective collection area.
b_e, b_i	electron, ion collision parameter.
c	velocity of light.
$\underline{c}$	resultant particle velocity.
E_e, E_i	electron, ion kinetic energy relative to satellite.
E_λ	intensity of radiation of wavelength λ.
$E_\perp$	perpendicular component of field intensity.
$\bar{E}$	electric field intensity.
e	electric charge.
h	Planck's constant.
I_e, I_i	electron, ion current.
I_{ph}	photoelectric current.
K	Boltzmann's constant.
L	angular momentum.
l	perpendicular distance from the satellite path.
m	mass of a particle (ion, or electron, or neutral particle).
m_e, m_i	electron, ion mass.
n_e, n_i	electron, ion number density.
n_0	ambient particle number density.
n	neutral particle number density.
P	ion momentum.
R	satellite radius.
$\bar{r}$	position vector.
S	power.
T_e	electron temperature (°K.).
V_e, V_i	electron, ion velocity.
V_s	satellite velocity.
$\bar{V}_s$	mean velocity of satellite relative to that of the ions.
V_0	velocity.
W	work function of the satellite surface.
y	parameter $= [e\phi(R) + W]/KT_e$.
Z	charge number.

Greek Symbols

α	parameter $2KT_e/m_e$.
Δ	parameter, Equation A.7.
θ_e, θ_i	electron, ion temperature (eV).
θ	angular coordinate.
λ	free space wavelength.
λ_D	Debye length.
μ	absorption coefficient.
$\bar{\mu}$	average absorption coefficient.
ν	frequency.
ρ_e, ρ_i	electron, ion charge density.
ρ_0	ambient charge density.
$\phi(r)$	potential energy of particle at a distance r from the satellite.
χ	distance within the wake.
ω	solid angle.

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ICE IN SPACE*

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(Communication from the Convair-Astronautics Division of General Dynamics Corporation)

ABSTRACT

The equilibrium temperatures and sublimation rates of various ices (H_2O, CO_2, CH_4, NH_3) in space have been determined as a function of solar distance and absorptivity. For example, a frozen H_2O sphere which absorbs all incident solar radiant energy, at a distance of one astronomical unit, has a steady state temperature of about 195° K. Under the same conditions, NH_3 remains close to 160° K., CO_2 close to 108° K. and CH_4 near 49° K. The corresponding decreases in radii per unit of time do not differ by more than a factor of ten for any of these four materials. Frozen water loses about 0·4 in./day for 100% absorption of incident radiation, 0·1 in./day for 50% absorption and 2×10^{-3} in./day for 7% absorption.

A flat transparent sheet of H_2O ice with a thickness of 1 cm. tends to remain at a temperature of $< 100°$ K. when at one astronomical unit from the Sun. At the corresponding mass loss rate, it would take a million years for it to sublimate, neglecting sputtering from solar corpuscular radiation.

I. INTRODUCTION AND SUMMARY

Now that the space age has started, problems involving temperature extremes in materials will become increasingly important. A lunar landing party, for example, may encounter ground temperatures as high as 370° K. at the subsolar point and as low as 120° K. for the point opposite to this. A knowledge of the low temperature properties of both ordinary solids, and solids which can exist only at low temperatures (*ices*), is therefore of value. However, we shall restrict our discussion to the latter category and, in particular, deal with the properties of ice in space. The word *ice* will be used in a general sense, referring to materials which have melting points, at atmospheric pressure, of 400° K. or less.

The main objective of this paper is to obtain an insight into the various properties of ices in space. For example, the equilibrium temperatures, sublimation rates and lifetimes are of great interest. Other parameters such as the albedo, reflection coefficient, transmissivity, surface texture, shape, structure, and chemical make-up are tied in with longevity and are also important.

The presence of ionizing radiation, either from the Sun or, *e.g.*, from a nuclear power source, adds an additional complexity to the solid state. This is especially true at low temperatures where radicals, or metastable atoms, may become frozen in a suitable cold matrix. Thus ice in space may be able to carry large amounts of stored energy. The comet may be an example of a body that carries enough energy, in the form of frozen radicals and atoms, to completely demolish itself, if this energy were released all at once. Rocket fuels may someday contain sizable amounts of metastable states, *e.g.*, metastable neon.

Another objective is to suggest possible uses for ices in astronautics as well as to point out certain possible hazards with the storage of ice in the presence of ionizing radiation. For example, solid oxygen may slowly become poisonous and explosive, from the creation of ozone.

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Finally, a discussion of H_2O ice is included since it is the only type that is well known. However, at least seven crystalline varieties are known to exist, although only one type exists at low pressures. This is the ordinary ice cube variety which is known technically as ice I. Our discussions will, therefore, pertain only to ice I. An amorphous variety which is stable at low temperatures will be mentioned later.

In calculating such quantities as the equilibrium temperature and sublimation rate, it is assumed that the ice body is at this temperature in the first place. If this is not the case, then the body tends to approach this temperature. During the subsequent transient period, the calculated sublimation rate would not be quite correct. However, since ices are usually very poor heat conductors, the surfaces would quickly approach the equilibrium value, while the interior would be at a somewhat different value, but slowly changing. The results are therefore approximate, the sublimation rate always being slightly too small when the interior temperatures are below the equilibrium temperature and too large for the alternate case. When the temperature differential is small, the error is negligible. Also, there are various corrections that can be used; for example, the heat of sublimation can be modified slightly. Another favourable situation is where the thermal energy required to make up the difference is small compared to the energy required to sublimate the entire body.

The advantages of neglecting conductivity are that the mass loss rates become independent of the cross sectional areas, and the formulae are relatively simple.

An interesting result of this study pertains to the mass loss rates from spheres of such radically different ices as HO_2, CH_4, NH_3, and CO_2. The vapour pressure differences of these ices differ by factors of 10^{10} at some temperatures. Nevertheless, if spheres of each of these ices are orbiting the Sun at 0·5 astronomical unit, the sublimation rates agree within a factor of 10. This rather surprising result is illustrated graphically in Fig. 1.

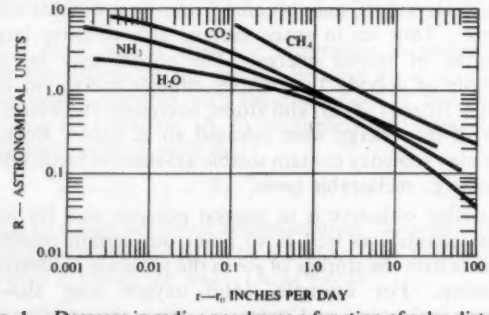

FIG. 1. Decrease in radius per day as a function of solar distance for spheres of ice sublimating in space at their equilibrium temperatures (see Fig. 13), assuming 100% absorption of solar radiation

It is also seen from this figure that a sphere of H_2O ice, which absorbs all of the Sun's radiation, loses about 0·4 in./day at the Earth's distance from the Sun. If the sphere reflects 97% of the solar radiation, it is found from Fig. 9 and 12 that the equilibrium temperature is 147° K. and the loss in radius is about 2×10^{-5} in./day. This might correspond to ice with a surface resembling hoarfrost.

However, years ago, Bunsen[1] demonstrated that when H_2O ice was carefully frozen, so as to be free of air bubbles, it "was equal to the best crystal glass in clearness and transparency." Thus, in Section XII we have taken a transparent slab of ice with an attentuation coefficient of 0·006 cm.$^{-1}$ and calculated the equilibrium temperatures and sublimation rates. It was found that at an incident angle of 45°, a sheet with a thickness of 1 cm. has an equilibrium temperature of 100° K. when at one astronomical unit from the Sun. At this temperature, it would last for several thousand years!

Since other ices may have greater transparencies, it is not impossible that, at times, chunks of ice would be encountered in space, *i.e.*, ice meteorites. The temperature does not have to drop very much more in order for frozen water to become a stone in almost every sense of the word!

II. FRESH-WATER ICE

It is common knowledge that clean fresh water when carefully frozen, so as to be free of locked-in air bubbles is optically clear, although in large masses it is a vivid blue. The blue colour can be attributed to scattering by the large ice molecules, while the clarity is a consequence of the small absorption coefficient, α, associated with Lambert's law

$$I = I_0 \exp(-\alpha\chi).$$

The presence of small dust particles will scatter the shorter wavelengths and tend to increase the absorption. Hawkes[2] has suggested that the "flowers of ice" phenomenon* can be explained by assuming that each dust particle acts as an absorber of radiant energy, and causes local melting in its vicinity. Ice which contains myriads of small hollow cavities may be a good scatterer or diffuse reflector.

For wavelengths of a micron (μ) or more, clear ice becomes a good absorber.

Eskimos after making an igloo from packed snow, build a fire on the inside and thereby effect a transformation of the inner wall surfaces so that they resemble pure rime ice (the surface of rime ice has the appearance of hoarfrost, which is an excellent diffuse reflector in the visible spectrum and a little beyond). Thereafter, only a small lamp, which burns seal blubber or some suitable substitute, is needed to maintain the internal temperature in the neighbourhood of 68–70° F. A translucent slab

* Tyndall[3] observed that numerous cavities resembling air bubbles will appear when a beam of light is directed into a block of ice—provided that the ice is not too far below its melting point. When examined under a microscope, these ice flowers appear as a bright nucleus surrounded by coplanar petals. The plane of each petal is perpendicular to the optic axis of its associated crystal.

of fresh-water ice can then be mounted in the roof for illumination. A convex slab can be used for a crude radiant heater; indeed the explorer Scoresby found that he could make magnifying lenses out of clear ice. Using these ice lenses, he could concentrate the Sun's rays and produce intense heating without melting the lenses.

However, it is also known that an ice cube placed on the ground in direct sunlight soon loses its shape by melting. On the basis of such observations, many persons would be inclined to doubt that a much longer lifetime could be realized by a similar chunk of ice in empty space (at the same distance from the Sun). That the above conjecture is incorrect can be inferred from the following arguments:

(1) In space, the ice chunk will not receive heat by convection or conduction, and it is these mechanisms that destroy ice on the ground.

(2) As will be shown later, ice in space will sublimate directly, in lieu of melting and spreading over the warm ground, which suggests that the process will take longer.

(3) Also because of sublimation, the temperature of ice in space at the Earth's distance from the Sun will be far below its temperature in the Earth's atmosphere where the sublimation rate is reduced by the presence of foreign gases (just as the sublimation rate of tungsten in an electric lamp is reduced by an atmosphere of nitrogen gas). This implies that the vapour pressure, and hence the rate of sublimation will become small.

(4) Ice in space will lose energy by radiative heat transfer over its entire surface area whereas the thermal influx is received over a smaller cross sectional area. For example, the radiating surface area of a sphere of ice I is about five times the equivalent absorption cross section, as will be shown later.

(5) Thin pieces of ice will transmit or reflect most of the visible spectrum.

(6) According to Fresnel's reflection formula for transparent bodies, many configurations can approximate nearly perfect reflectors, *i.e.*, when the angle of incidence is 85° or more. Certain configurations, such as a wedge, or slowly turning disc on edge, will be very poor receivers of solar energy.

(7) An ice body in space which has a snow-like surface or a surface made up of minute crystals may be an excellent diffuse reflector. Ordinary snow has a factor of entrapment of only 0·30 at most. Thus, a snowball in space would reflect 70% of the incident solar radiation, or more. Subliming gases will continually recondense on the dark or shadow surfaces* and the resulting deposit, at very low temperatures, is often an excellent diffuse reflector.

(8) Ices in the crystalline form will sublimate at a reduced rate. This has become evident from studies made by Frank,[4] Sears,[5] and others, which showed that crystal growth (deposition) and sublimation was limited by two-dimensional nucleation of new atomic layers. That is, molecules can leave or join the crystal only at certain particular points. This can materially reduce the rate of mass transfer.

(9) The sublimation rate is often diminished by surface contaminants which may reduce the accommodation coefficient.

Thus, for these and other reasons, ices in space may have long lifetimes, and may someday be used for construction, as well as an emergency heat sink, etc.

The rate at which ice is warmed by solar radiation is retarded by such mechanisms as sublimation, reflection, transmission, radiation and endothermic reactions. In the last category, one can include transitions in the crystalline or amorphous state, and disturbances of chemical equilibria in accordance with le Chatelier's principle which, in thermochemistry, is analogous to Lenz's law in electromechanics. In essence, it states that if a stress is brought to bear on a system in equilibrium, a change occurs such that the equilibrium is displaced in a direction which tends to undo the effect of stress.

For example, take the reaction

$$A + B \rightleftharpoons C + \Delta H,$$

which is exothermic when going to the right (by definition). Now, at a later time, after ΔH has vanished, say, because of radiation cooling, suppose that the temperature starts increasing and that either A, B or C has the higher vapour pressure, and, accordingly, begins to evaporate faster than the remaining members of the reaction. If B is that member, then the reaction will go to the left, which is endothermic. The above principle should apply to solutions in equilibria, including gas and solid solutions in addition to mixed crystals.

Endothermic reactions may therefore be extremely important in reducing the sublimation rate of ices which tend to form solid solutions, such as hydrocarbons. However, this will not be carried any further at this time since it would have to be verified and continued in the laboratory.

III. NATURALLY OCCURRING ICES IN SPACE

The comet is an example of a dusty snowball in space. It may consist of a porous conglomerate of heterogeneous ices (NH_3, CO_2, H_2O, etc.), including hydrates ($CO_2.6H_2O$), and dust particles. At times, a new (long period) comet may come very close to the Sun,

* The reasons for this will be given in a future paper

even passing through the corona, and still survive. One reason why it need not be destroyed is that during such passages, it is under intense radiation for only a very short time (hours). Also, the dust and gas, which is released in large quantities at such times, forms a protective screen which effectively raises the albedo.

As an example of a high-speed transit around the Sun, there is the comet of 1843 which came within 100,000 miles of the Sun's surface (0·011 A.U.). The entity swung through a complete 180° arc in only two hours and had a maximum speed of 350 miles/sec.

There are other naturally occurring ices, besides what is found on planets. For example, the rings of Saturn are believed to be made out of frozen water, and some of the moons of the major planets may contain tremendous quantities of ices.

IV. SOME POSSIBLE USES FOR ICE IN ASTRONAUTICS

There are probably many liquids that form highly transparent ices, or glasses, when frozen. The higher the transmissivity, the lower the temperature and sublimation rate. Thus, a material which is ordinarily thought of as highly volatile could freeze down to a low-vapour-pressure solid in a short time if it transmitted and reflected most of the solar spectrum. It may be desirable, for example, to store fuels and waste products on the outside of space vehicles. The more volatile fuels could be kept on the shadow side in solid form where they would offer some protection against meteorites. Waste liquids could be located at the front of the ship, where they would freeze and act as deflectors of the faster and most dangerous meteorites. The fuel would always be very cold and a small amount of sublimation would compensate for the heat radiated by the vehicle. A metal-coated plastic could also be used to cover the ices for an additional heat reflector. The ice would be separated from the vehicle to prevent heat conduction.

The idea of using liquids as cements to join and seal sections of space vehicles and space stations is also of interest. Not much can be said regarding the structural properties of ice I since very little, if any, pertinent research has been undertaken. The effects of additives, etc., have not been determined. Dorsey[6] summarizes most of the important measurements, *e.g.*, frozen water is both plastic and brittle. When sawn at 255° K. it splinters considerably, while at 272° it can be sawn easily. Between 263 and 273° K., the elastic modulus of ice I is about 14% and the shear modulus about 40% of the corresponding values for rolled aluminium. The crushing strength, at best, is about 30–60% of the values for crushed brick and it can be better than some concrete. On Moh's scale, the hardness is about 1·5, between talc and gypsum.

The idea of returning instruments to the Earth by placing them in an ice-coated sphere appears intriguing. During the descent the ice would gradually sublimate, or melt and vaporize, but the temperature would not rise above some particular equilibrium value less than the melting point. Thus, the danger of thermal damage would not exist so long as the ice remained. The atmospheric influences would be felt at altitudes below around 375,000 ft. Depending on the entry speed and angle, it would be possible to slow the package down from speeds of 4–6·9 miles/sec. to a few hundred miles/hr. a few minutes later. A parachute would then bring the payload to a soft landing. Since ice I can be made transparent, a camera or iconoscope could be mounted inside an ice window to transmit pictures of the hot boundary layer and eventually the ground. The atmosphere of Venus might be probed in this manner. Small animals could also be returned to Earth with this technique by using an internal air cavity. A winged prolate spheroid might be a useful configuration for this purpose, since it would not tumble.

V. ON THE "MELTING" OF ICE *IN VACUO*

If an ice receives heat continuously from the Sun it will either melt and then vaporize or vaporize directly (sublimate), depending on the external pressure. Referring to Fig. 2, if the pressure is below the value

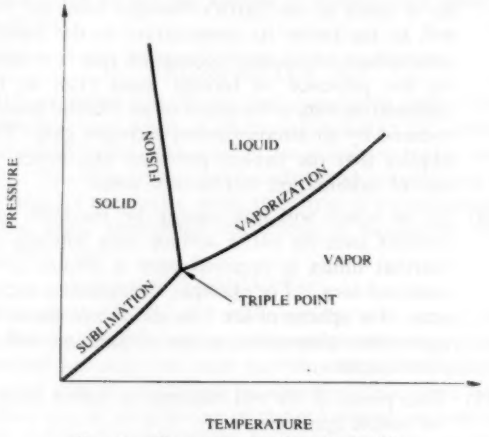

FIG. 2. Phase diagram for a typical ice

corresponding to the triple point it will sublimate. This is a consequence of the fact that the slopes of the sublimation and vaporization curves are always positive. Although the slope of the fusion curve can be negative, it cannot exceed 180°, for otherwise, as the temperature was increased, a liquid could change into a solid, which is contrary to experience. It is evident, therefore, that bodies in empty space will sublime rather than melt and vaporize.

An exception to this occurs in the case of helium, which cannot be solidified, no matter how low the temperature, unless the pressure is sufficiently high. Although there may be other exceptions, in general, small bodies in space are either solids or gases.

Of course, very large bodies by virtue of their gravitational fields are capable of maintaining an atmosphere,

and since their surfaces are under atmospheric pressure, melting is possible.

Internal melting of ice in a vacuum may occur if the ambient temperature is not too much below the melting point. For example, many ices are transparent or diathermic, and radiant energy will be absorbed beneath the surface. This is especially so if the ice contains small inclusions, such as dust particles, in the interior. Also, internal stresses may create regions which are susceptible to melting. Porous ice may not have sufficient internal pressure to melt.

Finally, heat which is conducted from the surface to the interior may cause melting. Tyndall[3] has shown experimentally that the interior portions of a mass of H_2O ice may be liquified by heat which has been conducted through unmelted exterior regions.

VI. SUBLIMATION

There are always gas phases at the surfaces of solids and liquids, since according to the kinetic theory, from time to time there will be molecules with enough kinetic energy to overcome the surface forces and escape. A portion of these free molecules will recondense, since a gas expands in all directions. If the solid is in a closed container, the rate of sublimation and condensation will eventually become identical, whereupon the vapour is said to be saturated. This is then the basis for the definition of vapour pressure. The vapour pressure of a substance at a given temperature is defined as the saturated equilibrium vapour pressure at that temperature. Unfortunately, this definition is not too suitable for sublimation problems in space where equilibrium conditions are not possible.

Instead of vapour pressure, a quantity such as the mass loss rate *in vacuo* at any given temperature would be preferable. However, it is not as bad as it could be, because Langmuir[7] discovered that "at temperatures so low that the vapour pressure of a substance does not exceed a millimetre, we may consider that the actual rate of evaporation of the substance is independent of the presence of vapour around it." In the following, we shall make use of Langmuir's observations.

1. The Rate of Sublimation in a Vacuum

The rate at which mass is transferred from the surface of a liquid (evaporation) or solid (sublimation) to a vacuum is of considerable commercial and scientific importance. For example, thermally sensitive materials such as blood plasma or antibiotics are commonly dehydrated by vacuum evaporation or "freeze-drying." Lenses and mirrors are frequently coated with evaporated metals, or inorganic salts, with very stringent tolerances on thickness. Scientifically the sublimation rate is tied in with the interfacial or surface resistance to mass transfer, which is not thoroughly understood.[8]

For our purposes, the mass transfer rate is needed in order to calculate the corresponding boundary surface temperatures. The well-known formula which pertains to this was originally given by Hertz,[9] and later by Langmuir,[7] Knudsen,[10] and finally Neumann.[11] The earlier authors made use of kinetic theory, while Neumann used statistical thermodynamics.

If $\frac{dm}{dt}$ is the rate at which mass is lost from a surface of area S, at temperature T, then[12]

$$\frac{dm}{dt} = -5{\cdot}833 \times 10^{-2}\alpha' S P_{mm}\left(\frac{M}{T}\right)^{\frac{1}{2}} \text{ g. sec.}^{-1} \ldots \quad (1)$$

where α' is the accommodation coefficient, P_{mm} the vapour pressure in mm of Hg, and M the molecular weight in Grammes. The influence of diffusional resistance is neglected.

The coefficient α' has a maximum value of unity but it may be considerably smaller, especially for solids.[8] For example, it is of the order of 10^{-9} for red phosphorous.[13] According to Tachudin,[14] the value of α' for water is $0{\cdot}94 \pm 0{\cdot}06$ over the temperature range -85 to $-60°$ C. Bruce[15] got a value of 0·44 at $-58{\cdot}4°$ C.

Since we do not want to overestimate the lifetime of ice in space (or underestimate the temperature) we shall take α' to be unity. We can always note the effects of a smaller α' by modifying P_{mm} accordingly.

Actually, α' depends a great deal on the purity of the ice and particularly the surface contamination. For example, Hickman and Trevoy[16] changed the rate of evaporation of glycerol by a factor of 40 over what others had reported by carefully cleaning the surfaces. Their value of α' approached unity.

VII. THE INTENSITY OF SUNLIGHT

The radiant energy at normal incidence, received by an area s at a distance R (in astronomical units) from the Sun is given by

$$I = \frac{0{\cdot}0331s}{R^2} \text{ cal.sec}^{-1}.$$

$$= 0{\cdot}1386s/R^2 \text{ watts} \quad \ldots \quad \ldots \quad (2)$$

As shown in Fig. 3, most of the energy lies between 0·3 and 2 μ in wavelength, while the maximum intensity is near 0·48 μ. The integrated energy for wavelengths greater than 2·5 μ is almost exactly 2% of the total energy radiated and is therefore of little importance.

VIII. BLACK BODY RADIATION

A black body at a temperature T will radiate according to the equation

$$E = \epsilon\sigma ST^4 \text{cal.sec.}^{-1}$$

where ϵ = emissivity at the temperature T,

$\sigma = 1{\cdot}374 \times 10^{-12}$cal.cm.$^{-2}$ sec.$^{-1}$ °K,[4]

S = radiating area,

and T = absolute temperature (° K.).

The emissivity of ordinary H_2O ice was determined by Schmidt.[17] A black body was taken as unity. It was found that for wet ice at 0° C., $\epsilon = 0{\cdot}966 \pm 0{\cdot}003$, for

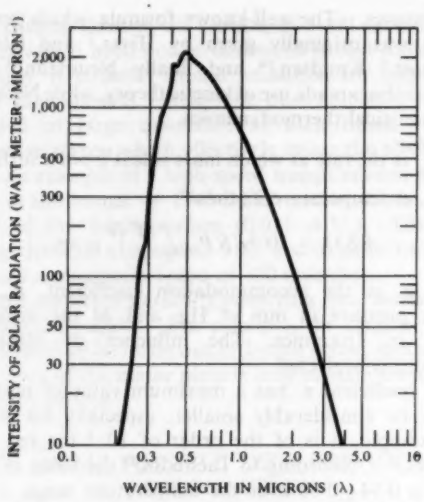

FIG. 3. Intensity of solar radiation as a function of wavelength in microns (one micron = 10^4 Å.)

transparent ice at −9·6° C., $\epsilon = 0{\cdot}965 \pm 0{\cdot}003$, and for white frost at −9·6° C., $\epsilon = 0{\cdot}985 \pm 0{\cdot}003$. It did not matter whether the frost was deposited on brass or ice.

By definition, the absorptivity is identical to the emissivity at the same temperature and wavelength. Thus, hoarfrost, which is almost a perfect diffuse reflector in the middle region of the spectrum, has an absorptivity of 98·5% for wavelengths corresponding to radiation at −9·6° C. From Wien's displacement law, this corresponds to a wavelength of

$$\lambda(\mu) = 2880/T = 10{\cdot}9\mu \quad .. \quad .. \quad (3)$$

According to Jakob,[18] hoarfrost comes closer to an ideal black body than any other material investigated.

IX. REFLECTIVITY

Freshly fallen powdery snow has a reflectivity close to 97% in the region from 0·4 to 0·8 μ and about 88% from 0·3 to 0·4 μ.

Ordinary H_2O ice has an emissivity and absorptivity of approximately unity in the wavelength region beyond 3 μ. In the visible spectrum ice is highly transparent and the reflectivity can be computed approximately from Fresnel's formula[6]:

$$R(i,n) = \tfrac{1}{2}\left\{\left[\frac{\sqrt{n^2 - \sin^2 i} - \cos^2 i}{\sqrt{n^2 - \sin^2 i} + \cos^2 i}\right]^2 + \left[\frac{n^2\cos^2 i - \sqrt{n^2 - \sin^2 i}}{n^2\cos^2 i + \sqrt{n^2 - \sin^2 i}}\right]^2\right\} \quad .. \quad (4)$$

where n is the index of refraction and i the angle of incidence. The index of refraction for H_2O ice is about 1·30 throughout the visible spectrum. A plot of R versus i from Equation (4) is shown in Fig. 4 for H_2O ice. The percentage of the incident energy reflected from various transparent ices by normally incident light as a function of n is shown in Fig. 5.

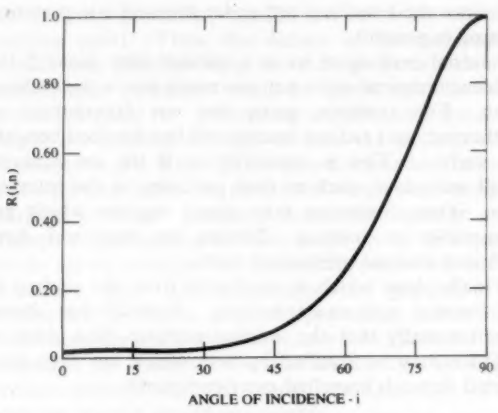

FIG. 4. Reflection coefficient for transparent water ice, assuming non-polarized light and an index of refraction of 1·30

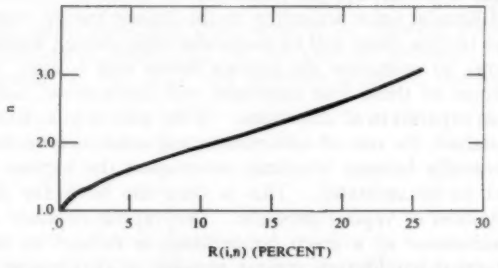

FIG. 5. Reflection coefficient, as a function of refraction index, for light incident perpendicularly on a plane transparent surface

X. THE EFFECTIVE CROSS-SECTION OF A TRANSPARENT SPHERE

It is evident that a portion of a light beam which is intercepted by a sphere will never enter the sphere because of reflection. Furthermore, the angle of incidence varies over the surface as shown in Fig. 6. If it is

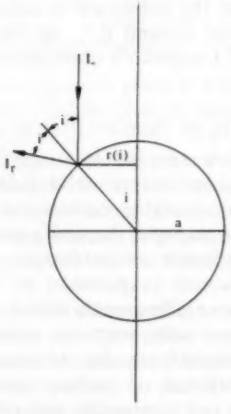

FIG. 6. Geometrical relationship for light incident on a transparent sphere of radius a

assumed that the reflection is specular, then a parallel beam of incoming radiation with intensity I_0 W.cm.$^{-2}$ will be partially reflected, depending on the incident angle i and refractive index n, according to

$$P_r = I_0 \int_a^0 R(i,n) 2\pi r(i) dr(i) \quad .. \quad .. \quad (5)$$

where P_r is the reflected power. The parameter $r(i)$ is given by

$$r(i) = a \sin i, \quad .. \quad .. \quad .. \quad (6)$$

and

$$dr(i) = a \cos i \, di, \quad .. \quad .. \quad (7)$$

where a is the radius of the sphere. Now eliminating $r(i)$ and $dr(i)$ from Equation (5) by employing Equations (6) and (7) and integrating over all possible angles of incidence, yields

$$P_r = \pi a^2 I_0 \zeta(n) \; .. \quad .. \quad .. \quad (8)$$

where

$$\zeta(n) = \int_0^{\frac{\pi}{2}} R(i,n) \sin 2i \, di \quad .. \quad (9)$$

If ζ is unity, which corresponds to a perfect reflector, then $P_r = \pi a^2 I_0$, as one would expect. In general, the integral is less than unity, and clearly, the power flow into the surface is given by

$$P_r = \pi a^2 I_0 [1 - \zeta(n)] = \pi a^2 I_0 \gamma(n), \quad .. \quad (10)$$

from which the effective cross-sectional area of the sphere, s', is

$$s' = \pi a^2 \gamma(n) = s\gamma(n) \quad .. \quad .. \quad (11)$$

A curve showing the variation of $\gamma(n)$ with the refractive index n is given in Fig. 7. For a sphere of pure H_2O ice,

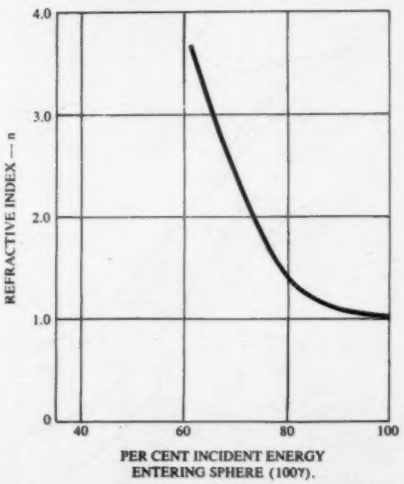

FIG. 7. Percentage of solar radiation entering a transparent sphere as a function of refractive index

$\gamma(n)$ was found to be 0·1847, which is equivalent to a disc of radius a, tilted so as to make an incidence angle of about 55°. The accommodation coefficient, α', which depends on the surface purity, may drop the equivalent cross-sectional area still more. The extremes of α' as reported in the literature for H_2O would put $\gamma(n)$ between 0·36 and 0·77. Also, we assumed that the sphere absorbed all of the diffracted light. A small sphere may transmit a sizable amount of the refracted light. For example, if it transmitted 50%, the range of values would drop in half, *i.e.*, to 0·18–0·39.

Apparently, an icicle with the pointed end headed toward the Sun would suffer very little from sublimation, *i.e.*, provided the cone angle was small, say 9°. A disc on edge might also have a very long lifetime in space. It has the advantage of having large radiating areas close to all interior points. This is especially important in the case of transparent bodies, which are heated internally rather than at the surfaces by radiant energy. Most of the internal energy would be conducted to dark surfaces and reradiated. The illuminated surfaces could, therefore, remain relatively cool.

Ordinary water vapour when condensed on a cold surface below 163° K. is vitreous, *i.e.*, optically isotropic, and can, therefore, be considered a glass.[19] Under these conditions, it is a true glass rather than an undercooled, highly viscous liquid, as might be deduced from Fig. 2. A discussion of these two types of vitreous glasses has been given by Simon.[20]

Many organic compounds, especially those containing several hydroxyl groups per molecule form glasses when reduced sufficiently in temperature. Nitrogen at a few degrees Kelvin has been reported to be crystalline.[21]

XI. EQUILIBRIUM TEMPERATURE OF A SPHERE IN SPACE NEGLECTING HEAT CONDUCTION AND DIATHERMANCY

The cross-sectional area πa^2 and the total surface area $4\pi a^2$ will be denoted by s and S, respectively. In addition, a small rotational component is assumed, in order to justify the assumption that the surface temperature is constant over the surface.

The power flow across the surface of the sphere must be conserved if there are no sources or sinks. If sublimation is considered to be a power loss then we have, from conservation of power, at the surface

$$\frac{0{\cdot}0331\,\gamma s}{R^2} - \epsilon\sigma S T^4 - l_s \frac{dm}{dt} = 0, \quad .. \quad (12)$$

where γs is the effective absorption cross-section of the sphere, l_s, is the heat of sublimation, and m the mass.

Now, eliminationg $\frac{dm}{dt}$ from Equation (12) by using Equation (1) gives

$$\frac{0{\cdot}0331\,\gamma s}{SR^2} - \epsilon\sigma T^4 - 0{\cdot}0583\,\alpha' l_s P_{mm} \left(\frac{M}{T}\right)^{\frac{1}{2}} = 0, \quad (13)$$

which can be reduced to

$$R^2 = \frac{\gamma}{1{\cdot}66 \times 10^{-10} \epsilon T^4 + 7{\cdot}049 \; P_{mm} l_s \alpha' (M/T)^{\frac{1}{2}}} \quad (14)$$

since the ratio S/s is equal to four.

Ordinarily, l_s and P_{mm} can be found from tables which give these values as a function of temperature. Since the radius cancels out in Equation (14), the equilibrium temperature is independent of it. This would not be the case if thermal conductivity had been included.

When tables are not available, an equation of state can often be found which relates P_{mm} to T, by integrating the Clausius-Clapeyron equation. Dushman[12] gives several such equations.

If the body is not sublimating, Equation (14) becomes

$$R = \frac{77{,}600}{T^2}\sqrt{\frac{\gamma}{\epsilon}} \quad .. \quad .. \quad (15)$$

or

$$T = \frac{278{\cdot}5}{\sqrt{R}}\sqrt[4]{\frac{\gamma}{\epsilon}}$$

The most convenient way for calculating the equilibrium distance from the Sun, is to insert values of P_{mm} and the corresponding values of T in Equation (14) and then solve for R. Equation (15) is plotted in Fig. 8 for

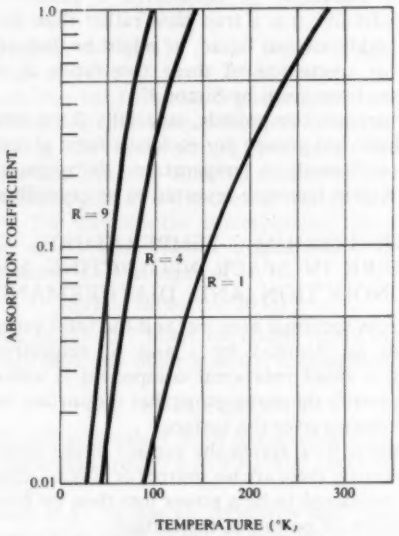

FIG. 8. Equilibrium temperature of a sphere in space, at R astromical units from the Sun, which has unit emissivity and absorptivity. Heat conduction, sublimation and diathermancy were neglected

various values of R and γ. We have taken ϵ to be unity. Equation (14) is plotted for a few materials in Fig. 9 to 13.

The rate at which mass is lost from the surface of a sphere is given by

$$\frac{dm}{dt} = 4\pi r^2\rho\frac{dr}{dt} = \rho S\frac{dr}{dt}$$
$$= -\,5{\cdot}833 \times 10^{-2}\alpha' P_{mm} S(M/T)^{\frac{1}{2}} \quad (16)$$

from Equation (1). From the two expressions on the right-hand side, we have

$$\frac{dr}{dt} = -\,5{\cdot}833 \times 10^{-2}\alpha' P_{mm}\,(M/T)^{\frac{1}{2}}/\rho \quad .. \quad (17)$$

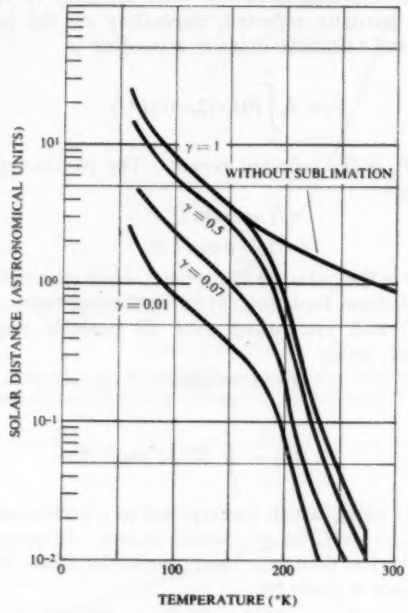

FIG. 9. Equilibrium temperature of a sphere of water ice, in space, which absorbs 100γ% of the incident radiant energy. The heat of sublimation was assumed to be 678 cal. g^{-1}

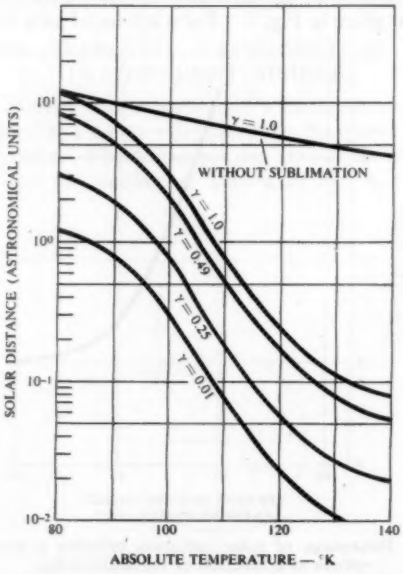

FIG. 10. Equilibrium temperature of a sphere of carbon dixode ice, in space, which absorbs 100γ% of the incident radiant energy. The heat of sublimation was assumed to be 137·8 cal g.$^{-1}$

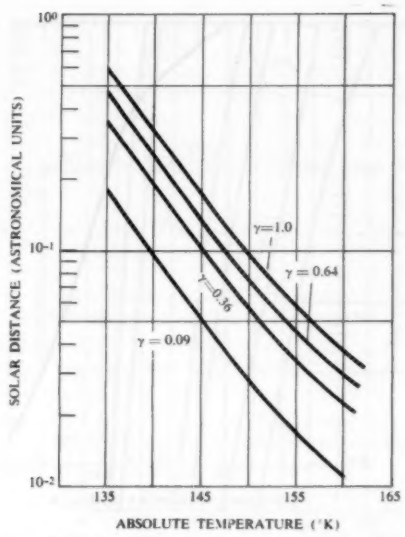

FIG. 11. Equilibrium temperature of a sphere of ammonia ice, in space, which absorbs 100γ% of the incident radiation. The heat of sublimation was assumed to be 450 cal g.$^{-1}$

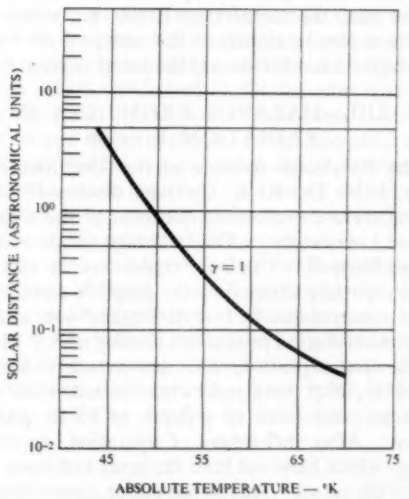

FIG. 12. Equilibrium temperature of a sphere of methane ice in space which absorbs 100% of the incident radiant energy

If the body is in equilibrium, *i.e.*, steadily losing mass but at the same temperature, then from Equation (17), the loss in radius after time t is

$$r_0 - r = 5{\cdot}833 \times 10^{-2}\alpha' t P_{mm} (M/T)^{\frac{1}{2}}/\rho \quad .. \quad (18)$$

For H_2O, since $\rho = 0{\cdot}91$ g. and $M = 18$, we have

$$r_0 - r = 0{\cdot}272\,\alpha' t P_{mm}/T^{\frac{1}{2}} \quad .. \quad .. \quad (19)$$

Equation (18) is plotted in Fig. 14 for several different ices.

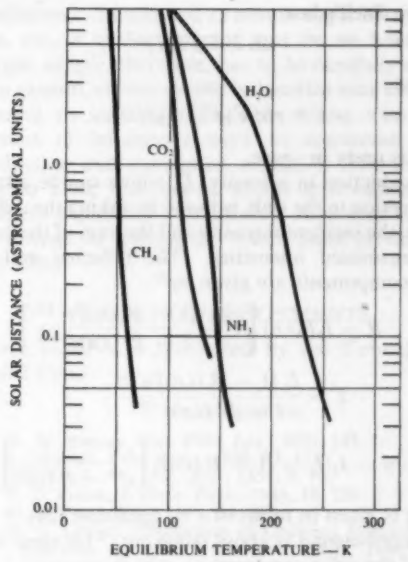

FIG. 13. Equilibrium temperatures for various ice spheres which absorb 100% of incident solar energy

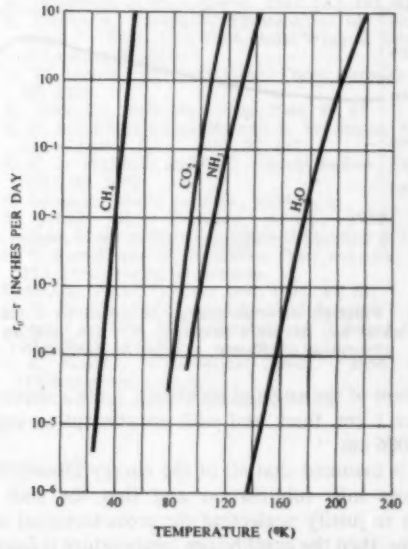

FIG. 14. Decrease in radius per day, as a function of absolute temperature, for spheres of ice sublimating in space

XII. THE TRANSPARENT SLAB

Consider a slab of ice with plane parallel faces and thickness h. Assume that the material obeys Lambert's absorption law and let α be the absorption coefficient. If the angle of incidence is i and the angle of refraction r, then the oblique thickness t along the internal ray is

$$t = h \sec r \quad .. \quad .. \quad .. \quad (20)$$

But from Snell's law

$$\sin i = n \sin r$$

and hence

$$t = nh/\sqrt{n^2 - \sin^2 i} \quad .. \quad .. \quad (21)$$

since n is unity in space.

The reduction in intensity, I_a, which can be attributed to absorption in the slab, is found by taking the difference between the incident intensity and the sum of the reflected and transmitted intensities. The reflected and transmitted components are given by[22]

$$R = I_0 R(i,n)\left[1 + \frac{[1 - R(i,n)]^2 e^{-2\alpha t}}{1 - R^2(i,n)e^{-2\alpha t}}\right] \quad (22)$$

and

$$T = \frac{I_0 [1 - R(i,n)]^2 e^{-\alpha t}}{1 - R^2(i,n)e^{-2\alpha t}} \quad .. \quad .. \quad (23)$$

Hence

$$\gamma = I_a/I_0 = [1 - R(i,n)]\left[\frac{e^{\alpha t} - 1}{e^{\alpha t} - R(i,n)}\right] \quad (24)$$

where t is given in terms of i by Equation (21).

The coefficient α is about 0·006 cm.$^{-1}$ for clear ice over most of the solar spectrum.

The parameter γ, which indicates the fraction of solar energy absorbed by the slab, is plotted in Fig. 15 as

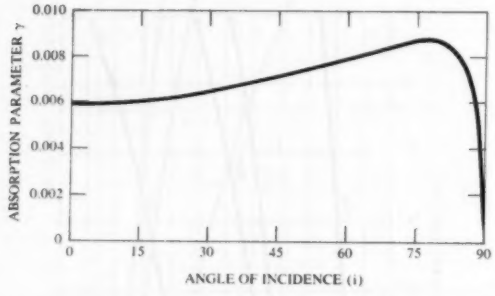

FIG. 15. Fraction of solar energy absorbed by a transparent slab of water ice, having a thickness of 1 cm. and an internal absorption coefficient, α, equal to 0·006 cm.$^{-1}$

a function of the angle of incidence, i, for a sheet of clear H_2O ice 1 cm. thick and with an absorption coefficient $\alpha = 0{\cdot}006$ cm.$^{-1}$

If it is assumed that all of the energy absorbed by the slab goes into sublimation and that the slab is thin enough to justify neglecting the cross-sectional areas on the sides, then the equilibrium temperature is found from

$$\frac{0{\cdot}0331\gamma}{2R^2} - \epsilon\sigma T^4 - 0{\cdot}05833\, P_{mm} l_s \alpha' (M/T)^{\frac{1}{2}} \quad .. \quad (25)$$

In particular, for water

$$R^2 = \frac{\gamma}{0{\cdot}8302 \times 10^{-10} T^4 + [(14{\cdot}95\, l_s \alpha' P_{mm})/T^{\frac{1}{2}}]} \quad (26)$$

The rate at which the slab diminishes in thickness is equal to twice the reduction in radius for a spherical shape at the same temperature.

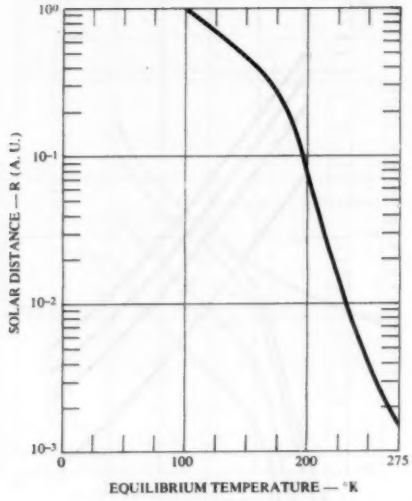

FIG. 16. Equilibrium temperature of the slab of ice in Fig. 15 for an angle of incidence of 45°, which corresponds to $\gamma = 0{\cdot}0071$

A graph of the equilibrium temperature of a slab 1 cm. thick is shown in Fig. 16 for H_2O. At the Earth's distance from the Sun, the temperature is 100° K., which corresponds to a loss in radius of the order of 10^{-9} in./day. The slab could last for several thousand years at this rate.

XIII. HAZARDS FROM ICES IN RADIATION FIELDS

At the Pittsburgh meeting of the American Physical Society, 1956, Dr. R. R. Coltman disclosed[23] that two low temperature explosions occurred at the Oak Ridge National Laboratory. Also, a similar single event took place at Harwell. The two explosions at Oak Ridge were in cryostats situated in the graphite reactor, where the fast neutron flux is 7×10^{11} n/cm.^{2}/sec. and where the gamma radiation produces a heating of 5×10^{-3} W./g.

In the first explosion, an open-mouthed aluminium dewar flask, 20 ft. long and located in hole number 12 of the reactor, was filled to a depth of 15 ft. with liquid nitrogen. After three days of operation, an explosion occurred which blew out both the inner and outer bottom plates of the vessel. An intense odour, resembling ozone, was noted on top of the reactor immediately following this event.

The second explosion also took place in hole number 12, inside a 22-ft. aluminium cryostat through which cold helium gas was circulating. However, there was a leak which allowed small quantities of air to freeze in the system for a period of 4–5 hr. At this time the temperature was 20° K. When the leak was repaired, the bombardment was continued and the ices were not removed. Upon completion of the bombardment, which lasted less than 180 hr., the unit was allowed to warm up overnight. The following morning it was found that an explosion had taken place during the night.

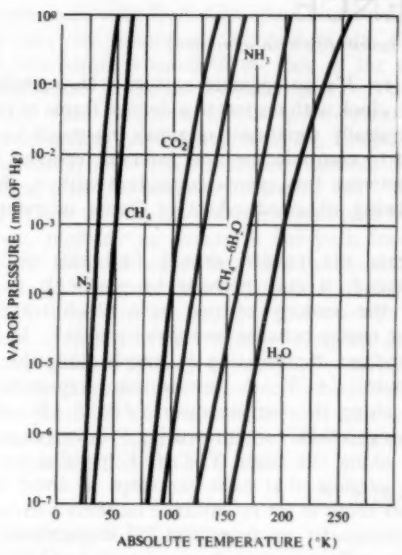

FIG. 17. Vapour pressures of solid ice.

Coltman believes that since the bottoms of three concentric cans had been blown out, there is a critical temperature at which the explosion tends to occur.

It is also believed that in each incident the fraction of oxygen which condensed in the cryostat was gradually turned to ozone by the reactor radiations. Although the exact nature of the explosion is not known, a few possibilities are evident, *e.g.*, a sudden decomposition of ozone, a nitrogen-ozone reaction, reaction of ozone with small quantities of foreign materials, or the recombinations of frozen radicals or metastable states.

In any case, it is evident that small quantities or concentrations of liquid or solid oxygen in the presence of intense ionizing radiations are hazardous.

This is very interesing because oxygen must be carried along during manned space flights in large quantities, and for long time periods. Even small quantities of ionizing radiation might be hazardous under these conditions. In addition to cosmic rays, X-rays from the Sun, etc., a nuclear reactor may be on board and the oxygen supply, therefore, has to be carefully shielded.

In general, all ices should be handled with caution when exposed to ionizing radiation. Along with the large amount of laboratory work in connection with the production and storage of molecular fragments, it has become clear that stored atoms and radicals can be excellent explosives. Explosions have even occurred at the Bureau of Standards, where most of this work is centralized.

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CORRESPONDENCE

(In these letters to the Editor, some passages have necessarily been ommitted)

Relativity and Space Travel

I cannot accept the validity of the argument given in Professor Dingle's letter.[1] If, as he suggests, we introduce a third clock R' on α Centauri, then the observations would be as follows.

With respect to M's co-ordinate system the clock R' is advanced during the initial acceleration of the rocket by approximately v^2T/c^2 where v is the final velocity of M relative to R and R', and T is the duration of the outward journey by R's clock. It is assumed that the acceleration periods are very small compared with the total duration of the journey and that M's co-ordinate system is derived from a set of inertial frames of reference, the one selected at each instant being that which is stationary with respect to the rocket. The outward journey has a duration αT by M's clock, where $\alpha^2 = 1-v^2/c^2$, and during this time the clocks R and R' run slow by a factor α. Hence, just before the second operation of the rocket, M observes that the reading on R' is T and plots the value αT for the reading on R's clock. During the second operation of the rocket R's clock is advanced by $2v^2T/c^2$ and subsequently, during the return journey lasting another αT by M's clock, R and R' again run slow by the factor α. During the final operation of the rocket R' is advanced by a further v^2T/c^2 bringing the readings on R and R' into synchronism at the value $2T$. So far as measurements with respect to R's co-ordinate system are concerned, R' remains throughout in synchronism with R's clock, while M's clock runs slow by the factor α during both the outward and the return journeys.

The observations made by each observer are in no way affected if it is assumed that R checks synchronism of R' after M's initial operation of the rocket instead of before this operation. M simply states that, according to his co-ordinate system, R has failed to synchronise R' with the clock at R correctly. It follows directly from the Lorentz transformation that R and R' cannot be in synchronism for both co-ordinate systems. Furthermore, the fact that the relative rates of R and R' are changed by a large factor with respect to M's co-ordinate system during each operation of the rocket motor does not imply that a corresponding change is observed with respect to R's co-ordinate system. Nevertheless, the rate of a clock with respect to a defined frame of reference is a physically significant quantity inasmuch as it may be used to compute the time interval recorded by that clock between two events coincident with it, the same result being obtained whatever frame of reference is chosen.

In case the reader should find this difficult to comprehend, it may perhaps be profitable to pursue further the analogy of two cars which travel along different routes between two given points.[2] In the diagram one car, representing R, travels along the straight line route $XACY$. A second car, representing M, travels along the longer route $XABCY$. To complete the analogy a third car representing R' is introduced which travels along the route $X'A'BC'Y'$ parallel to $XACY$. Let us suppose that each car stops at short intervals along its route to set up distance markers corresponding to the milometer readings, and for convenience assume that the milometers read zero at A and A'. Finally projections are made of the readings on the distance markers set up by R and R' on to the route followed by M, and of the readings on the distance markers set up by M on to the route followed by R.

It is seen from Fig. 1 that, for the first set of projections, each mile interval between A and B corresponds to an interval of more than a mile according to the distance markers set up by R and R'. In other words, M states that the milometers of R and R' were running fast. Similarly, when the projections from the distance markers set up by M on to the route followed by R are considered, it appears to R that M's milometer has been running fast. This "paradox" is, however, resolved when the discontinuities in the readings projected on to M's route at the points corresponding to each change in M's direction are considered. Moreover, these discontinuities have no bearing on the nature of the projections from the markers set up by R' on to the route followed by R.

The analogy differs from the space travel experiment in that M's milometer records the greater path length, whereas in the space travel experiment R's clock records the greater time interval. This is because in the analogy

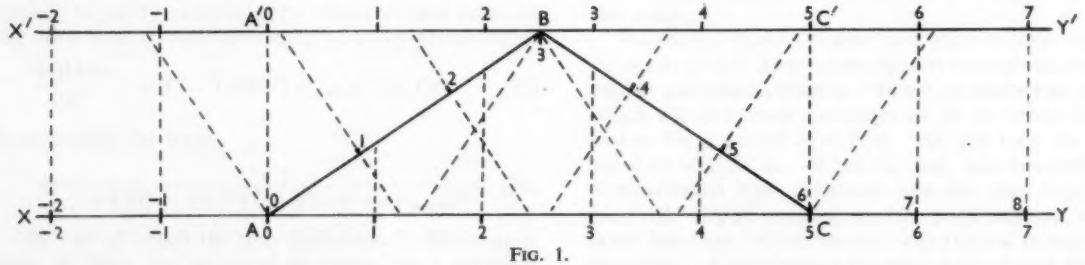

FIG. 1.

we are concerned with Euclidean space characterized by the fact that the square of the straight-line distance between two points is equal to the sum of the squares of the differences in the co-ordinate values. The four-dimensional space required for the geometrical representation of special relativity is, however, Euclidean (or quasi-Euclidean) only if the real time variable t is first transformed into the imaginary variable ict. In consequence of this, the straight line or geodesic path between two points, representing events, is the path for which the time and distance components are the greatest. As in the analogy, a transformation from one inertial frame of reference to another corresponds to a rotation of the co-ordinate system, but the angle of rotation must be represented by an imaginary quantity. Transformation of time or distance readings from one frame of reference to another therefore corresponds to a process of projection through an imaginary angle. This is explained in greater detail in References 3 and 4.

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22 *June*, 1959.

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Design of Step Rockets

SIR,

Mr. Argyle writes[1] that it is unrealistic to assume s to be constant, when the number of steps of a rocket is changed. I am in full agreement with this, but I doubt if the parameter σ, which Mr. Argyle uses, can be considered to remain constant under these conditions. I agree that it does not matter much when the number of steps of a rocket is changed from three to four, but I ask myself whether it is permissible to consider σ as a constant when the number of steps is increased from one to five. I therefore fear that the optimum for the number of steps which would be obtained from the graph is probably spurious.

Could Mr. Argyle mention the source where he found that the structural ratio of the Atlas is approximately fourteen?

Yours sincerely,

M. VERTREGT.

Mozartlaan 73,
The Hague, Netherlands.
24 *June*, 1959.

REFERENCE

1. P. E. Argyle, *J.B.I.S.*, 1959–60, **17**, 141.

Electrical Theory of Gravity

SIR,

The explanations given by Ba Hli[1] and Johnson[2] of why the dielectric constant of a medium will not affect the "gravitational" force between bodies[3], are very similar to each other, and we must admit their plausibility.

However, we are still left in some confusion on another aspect of the ingenious "electrical" theory of gravity as propounded by Dr. Ba Hli. This concerns the basic definitions of charge and electric field. In conventional electrostatic theory, a given electrical charge is associated with a given scalar magnitude of electrostatic field at a point *P independent* of the sign of any test charge placed at *P*. If we accept Dr. Ba Hli's concept, then the scalar magnitude of the field must now depend on the sign of the test charge in relation to that of the central charge.

How does Dr. Ba Hli propose to define the unit of charge and the unit electric field in his theory, bearing in mind there is not now a one:one correspondence between them?, We would very much like to see electromagnetic theory remodelled on the new basic assumptions.

Yours faithfully,

D. J. CASHMORE,
C. N. GORDON.

English Electric Aviation Ltd.,
Guided Weapons Division,
Luton Airport, Bedfordshire.
7 *September*, 1959.

REFERENCES

1. F. Ba Hli, *J.B.I.S.*, 1959–60, **17**, 141
2. Larry E. Johnson, *ibid.*, 140.
3. D. J. Cashmore and C. N. Gordon, *ibid.*, 1957–58, **16**, 586.

Languages at I.A.F. Congresses

SIR,

At the XIth I.A.F. Congress in Stockholm it is recommended that papers for presentation should be written in English. In the absence of any system of instantaneous translation this is a wise suggestion, as it was very noticeable at Church House last September how rapidly the hall emptied when a paper was read in any language other than English.

May I also suggest to those whose mother-tongue is not English and who propose to present papers that unless they are very confident of their English phrasing and pronunciation they should ask an English-speaking colleague to read their paper. Several papers last year were quite unintelligible (at least to me), because their authors were unable to express themselves clearly in the English language.

Yours truly,

R. G. D. NEWILL

Little Meadow,
Chipperfield, Hertfordshire.
11 *February*, 1960.

NEWS AND ANNOUNCEMENTS

B.I.S. NEWS

Assistance from Hawker Siddeley: Presentation to Sir Roy Dobson

Council desires to place on record its deep appreciation of the substantial assistance given to the Society by the Hawker Siddeley Group at the time of the Commonwealth Spaceflight Symposium and Tenth International Astronautical Congress. This assistance included not only a donation of £500 towards the cost of organizing the Congress, but also the seconding of several members of staff (one for a period of three months before the Congress), and the loan of cars and other equipment.

So that a more tangible expression of the Society's gratitude for this assistance could be made, Council commissioned from Mr. John W. Wood a painting depicting a pyramid satellite mounted on the Blue Streak vehicle—this type of satellite having formed the subject of a design study (presented at the Commonwealth Spaceflight Symposium) by Dr. H. R. Watson of Sir W. G. Armstrong Whitworth Aircraft Ltd., a member of the Hawker Siddeley group.

This painting was presented by Dr. L. R. Shepherd (Chairman of Council) to Sir Roy Dobson, Managing Director of the Hawker Siddeley Group, at a dinner given by the Council at St. Ermin's Hotel, Westminster, on 25 November, 1959.

The satellite shown in the painting represents a half-size model which could be tested with Blue Streak. The full-size pyramid is intended to carry a crew of two, and would require a more powerful launching vehicle.

Sir Roy Dobson receiving the painting from Dr. Shepherd

Fifteenth Annual General Meeting

The date chosen for the Annual General Meeting is **Friday, 15 July, 1960.** Members are remined that notice of nomination for election to the Council is required at least twelve weeks before the date fixed for the meeting. The nomination forms, which are obtainable from the Secretary, must therefore be completed and returned by **22 April, 1960.**

Election of Members

The following elections were made at the Council Meeting on 2 May, 1959:

New Fellows.

GEORGE BEARDSHALL, A.F.R.Ae.S., Normalair Ltd., Yeovil, Somerset.
WALTER EDWARD BRYANT, Grad. I.E.E., 156, Milton Avenue, East Ham, London, E.6.
ARTHUR CECIL CLARK, 2, Meadow Close, Old Windsor, Berkshire.
MICHAEL JOSEPH EDWARD COOLEY, 63*a*, Hamilton Terrace, St. John's Wood, London, N.W.8.
RONALD HERBERT THOMAS DIXON, A.I.M., A.C.T., 29, Jaffray Road, Erdington, Birmingham, 23.
CARL RICHARD DULGEROFF, A.B., Ph.D., 7443, Quimby Avenue, Canoga Park, Calif., U.S.A.
BRIAN EDWARD GLADHILL, "Cherry Pie," Bay Road, Freshwater Bay, Isle of Wight.
CECIL HUGHES, A.M.I.Mech.E., Teffont Magna, Salisbury, Wiltshire.
KENNETH WILLIAM CHARLES LAVANCHY, 23, Heronfield, Little Heath, Potters Bar, Middlesex.
WALTER C. NELSON, B.S., 1105E, South Street, Orlando, Florida, U.S.A.
PAUL ANTHONY PENZO, B.S., Ph.D., 3800, Strand, Apt. 6, Manhattan Beach, Col., U.S.A.
ROY EDWARD RODNEY SMITH, Jeffery's Orchard, Afton Road, Freshwater Bay, Isle of Wight.
WILLIAM ROBIN SOWREY, 51, Princess Gardens, Holywood, Co. Down, Northern Ireland.
HENRY LAURENCE THACKWELL, B.S., 1509, Highland Avenue, Redlands, Calif., U.S.A.
Professor WILLIAM TYRELL THOMSON, 417, Mesa Road, Santa Monica, Calif., U.S.A.
WALTER LEONARD ABIGAIL, A.M.I.Mech.E., A.F.R.Ae.S., 105, Grosvenor Road, Staines, Middlesex.

Members elected to the Fellowship.

GEORGE PHILIP MARTIN AHIER, Redcliff, Mount Rivel, St. Helier, Jersey, Channel Islands.
ROBERT ALAN CITRON, Smithsonian Satellite Tracking Station, Instituto y Observatorio de Marina, San Fernando, Spain.
JAMES BRIAN CLARKE, A.M.I.H.V.E., Crowther, McKay & Associates Ltd., 2nd Floor, Condon Bldg., 14th Street and 17th Avenue, S.W., Calgary, Alberta, Canada.
WILLIAM THORBY FISHER, A.F.R.Ae.S., 3, Buckingham Place, Bristol, 8.
MICHAEL REUBEN QUASTEL, B.Sc., M.D., C.M., 19, Philbeach Gardens, London, S.W.5.

Members elected to Senior Membership.

BRIAN MICHAEL SPRINGALL, Brecon Heath Lane, Blackfordby, Nr. Burton-on-Trent, Staffordshire.
WILLIAM ALVA HENRY THOMAS, Kingsleigh Court, Box 761, Milton, Ontario, Canada.

New Members.

KENNETH ALWYN, 54, St. George's Square, London, S.W.1.
DERRICK ARCHER, Brooklands, West Wells Road, Ossett, Yorkshire.
HERBERT JAMES BARRY, 40, Penkett Road, Wallasey, Cheshire.
DONALD CAMERON BUCHANAN, 557, Gerald Street, Ville Lasalle, Montreal 32, Quebec, Canada.
JAMES COSBY BYRD, Jnr., B.S., M.A., 510, Fairfax Avenue, Nashville 12, Tennessee, U.S.A.
WILLIAM CRANE CUNNINGTON, Bristol Siddeley Engines Ltd., Technical Records Dept., P.O. Box 3, Filton, Bristol.
ROBERT WAYNE DICKEY, Box 13, Callander, Ontario, Canada.
BERNARD GARNETT, 33, Monckton Road, Copnor, Portsmouth, Hampshire.
KLAUS GEHLEN, Cologne-Riehl, Riehler-Gürtel 62, Western Germany.
MICHAEL CHARLES GREGG, 317, Murray Avenue, Englewood, N.J., U.S.A.
JAMES HARDER, 43, Kirkdale Avenue, Leeds, 12.
CHRISTOPHER KELLEY HARVEY, 122, Rothwell Road, Desborough, Northamptonshire.
DAVID CHARLES KERRY, The Bungalow, Stoke Place, Slough, Buckinghamshire.
JAMES RONALD LEWIS, 17, Clitheroe Road, Collier Row, Romford, Essex.
ANSEN OZARDA, Dept. of Nuclear Medicine, Roswell Park Memorial Institute, Buffalo, N.Y., U.S.A.
ANDREAS PAPATHANASSIOU, A.R.Ae.S., 77, Eripidou Street, Athens, Greece.
ROGER PERKS, 34, Bosworth Road, South Yardley, Birmingham 26.
ELSIE RALLA, 12, Burrimul Street, Woomera, South Australia.
WILLIAM JOHN ROBINSON, B.Sc., Ph.D., 64, Malford Court, Woodford Road, London, E.18.
REGINALD LAKIN TURNER, "Plas Amherst," Harlech, Merioneth, North Wales.
PETER BRUCE WALTON, 34-41, 77 Street, Jackson Heights 72, New York, U.S.A.
Professor JOSEPH WILKOWSKI, University Observatory, Sloneczna 36, Poznan, Poland.

The following elections were made at the Council Meeting on 30 May, 1959:

New Fellows.

MARTIN FREDERICK ANSELL, B.Sc., Ph.D., St. Christopher's School, Beach Road, Hayling Island, Hampshire.
JOHN DAVID BROMLEY, B.Sc., Grad. R.Ae.S., 24, Byron Street, Todmorden, Lancashire.
GERALD WILLIAM BARNFIELD, 2, Rosedell, South Street, Uley, Nr. Dursley, Gloucestershire.
DAVID BRIAN COLLINS, Efford, Orton Lane, Wombourne, Wolverhampton, Staffordshire.
ANDRZEJ LUDOWIC ROMAN DZIWINSKI, Grad. R.Ae.S., 1, Orthes Grove, Heaton Chapel, Stockport, Cheshire.
MAURICE VIVIAN FOX-STRANGWAYS, A.F.R.Ae.S., Officers Mess, H.Q. Bomber Command, R.A.F., High Wycombe, Buckinghamshire.
C. D. J. GENERALES, 115, Central Park West, New York, 23, N.Y., U.S.A.
DOUGLAS MARSH, B.Sc., 39, Effingham Road, St. Andrew's Park, Bristol, 6.
BERNARD JOSEPH O'KEEFE, B.E.E., 39, Ridge Avenue, Natick, Mass., U.S.A.
ARNOLD RICHARD LINDGREN PEARCE, 15, Kingswood Avenue, Leicester.
DAVID B. SINGER, 1018, S. Hayworth, Los Angeles 35, Calif., U.S.A.
ALAN CHARLES NORMAN TUCKER, Grad. R.Ae.S., Lanchester Hall, College of Aeronautics, Cranfield, Bletchley, Buckinghamshire.
JAMES WALTER USELLER, B.S., National Aeronautics and Space Administration, Lewis Laboratory, 21000, Brookpark Road, Cleveland 35, Ohio, U.S.A.

Members elected to the Fellowship.

GEORGE DESMOND CUDDON, 22, Willow Grove, Coventry.
ERIC GREENSLADE, 145, Topsham Road, Exeter, Devon.
ROBERT HARDY, 85, Halsey Road, Elizabeth East, South Australia.
JESSE LAFAYETTE MITCHELL, B.S., 11306, College View Drive, Wheaton, Md., U.S.A.
LOUIS GEORGE VARGO, M.S., 1998, Pomona Avenue, Costa Mesa, California, U.S.A.
ALAN KENNETH WELCH, B.Sc., 184, Carlton Avenue East, Wembley, Middlesex.

Members elected to Senior Membership.

LILLIAN DEANS, Homebush Private Bag, Christchurch, New Zealand.
COLIN HERBERT SMITH, 3, Grange Road, Straight Road, Gidea Park, Romford, Essex.

New Members.

AILEEN ELIZABETH ANSELL, St. Christopher's School, Beach Road, Hayling Island, Hampshire.
GEORGE TERRENCE BARTON, 6, Wyken Cooft, Wyken, Coventry.
FREDERICK ROBERT BILLING, 7, Chesnut Street, Darlington, County Durham.
KENNETH CLAUDE BREED, 51, Collingham Gardens, Mackworth Estate, Derby.
LIONEL SHORT BUTCHER, Farchynys Lodge, Bontddu, Nr. Dolgelley, Merioneth, North Wales.
ARUN PRATAP SINGH CHAUHAN, B.Sc., Officers Mess, H.Q. Bombay Engineer Corp., Kirkee, Poona 3, India.
MICHAEL HARDING HARRIES, 3, Westcroft, Kingston Hill, Kingston, Surrey.
EDGAR HORNE, 22, Woodlands Drive, Brooklands, Sale, Cheshire.
EVERARD WERNER JUST, 25, Harris Street, Marton, New Zealand.
EDWARD FRANCIS KOLAR, 34, Hillcrest Road, Fair Haven, N.J., U.S.A.
DESMOND DAVID MACK, 63, Gilnahick Park, Belfast, Northern Ireland.
ROY MARSHALL, 26, Belper Street, Ilkeston, Derby.
CHARLES LINCOLN NILES, B.S., 943, South Bedford Street, Los Angeles 35, Calif., U.S.A.
GEORGE SOURINE, 95, Rue du Marechal Joffre, Colombres (Seine), France.
JOHN FOUNTEIN STEIN, Port O'Call, 2*a*, Brookfield Road, Bedford.
MICHAEL JOHN TAYLOR, 74, Boldmere Road, Sutton Coldfield, Birmingham.

The following elections were made at the Council Meeting on 4 July, 1959:

New Fellows.

W. GORDON ALLEN, B.S., Ph.D., 26, Hansen Avenue, Salem, Oregon, U.S.A.
PETER ARKWRIGHT, 312, Peter Street, P.O. Box 544, Markham, Ontario, Canada.
DAVID BENNETT, G.I.Mech.E., 18, Crouch Croft, New Eltham, London, S.E.9.
ALAN HUGH BEST, 21, Selby Road, Plaistow, London, E.13.
RONALD ALLAN COFFEE, Graduate I.E.E., D.I.C., 245, Norbury Crescent, Norbury, London, S.W.16.
HAROLD CECIL COLLINS, A.F.R.Ae.S., 21, Moorfield Road, Brockworth, Gloucestershire.
BERNARD DAVIES, 19, Rhos Avenue, Alkrington, Middleton, Nr. Manchester, Lancashire.
DESMOND EGAN-ANDREW, B.A., The White Cottage, New England Hill, West End, Nr. Woking, Surrey.
ALFRED EDMUND JEFFERSON, U.K. M.O.S. Staff, Box 1424 H, G.P.O., Adelaide, South Australia.
JOHN JEPSON, B.Sc., 4, Fern Lane, Haddenham, Buckinghamshire.
SEYMOUR LAMBERT, M.S., Ph.D., 13032, Eton Place, Santa Ana, California, U.S.A.
JOHN MCCULLOCH, A.F.R.Ae.S., 64, Marlborough Crescent, Sevenoaks, Kent.
STANLEY PUDDIFOOT, A.M.I.E.E., 15, Ewell Avenue, Hamilton Park, South Australia.
ROBERT WILLIAM PYE, B.A., Pear Tree Cottage, Greens School Lane, Farnborough, Hampshire.
JOHN ALBERT CHARLES REDDING, 5, Colham Villas, West Drayton Road, Hillingdon, Middlesex.
DEREK MICHAEL RHODES, 27, Chesholm Road, Stoke Newington, London, N.16.
PETER JOHN ROBBINS, 19, Brocks Road, Hartcliffe, Bristol, 3.
GEOFFREY ROBERTS, Westleigh, Meadfoot Lane, Torquay, Devon.
GEOFFREY FRANCIS SHARPLES, G.I.Mech.E., 6, Walesby Place, Ansdell, Lytham St. Annes, Lancashire.
Professor AUSTIN GEOFFREY SMITH, B.Sc., D.I.C., 6, The Drive, Wharley End, Cranfield, Bletchley, Buckinghamshire.
RICHARD FRANK TURTON, 32, Barnsley Road, Scawsby, Doncaster, Yorkshire.
LIONEL WILLIAM WOOD, 10, Broomfield Rise, Abbots Langley, Nr. Watford, Hertfordshire.
HARRY ZUCKERBERG, B.S., M.E., 4038, Ursula Avenue, Los Angeles 8, California, U.S.A.

Members elected to the Fellowship.

MICHAEL H. BRIGGS, B.Sc., F.R.A.S., Department of Chemistry, Victoria University, New Zealand.
MICHAEL J. W. COOLEY, 63*a*, Hamilton Terrace, St. John's Wood, London, N.W.8.
DONALD C. HARRIS, 29, Thornbury Road, Perry Barr, Birmingham, 20.
LEWIS D. HEAP, M.A., M.R.C.S., L.R.C.P., 11, Leamington Crescent, South Harrow, Middlesex.

ROBERT C. HENDRICKS, B.Ae.E., 16011, Valley View Avenue, Cleveland 35, Ohio, U.S.A.
BERNARD H. REYNOLDS, 65, Lynton Road, Acton, London, W.3.
KENNETH H. SAYERS, 35, Frith Road, Bognor Regis, Sussex.
BRIAN J. TOWNSEND, 182, Broadway, Yaxley, Peterborough, Northamptonshire.
REX S. WILKINSON, B.Sc., 5, Primrose Hill Road, London, N.W.3.

Members elected to Senior Membership.

H. C. C. HUNT, F.R.A.S., 5, Stoke Road, Aylesbury, Buckinghamshire.

New Members.

VERNON BECK, B.S., 1505, N. Durham Street, Baltimore 13, Md., U.S.A.
IAN RICHARD CAMPBELL-GRANT, 37, Elmsleigh Avenue, Kenton, Middlesex.
CARL BRITTON COX, M.A., 5223, 56th Avenue S., Seattle 18, Washington, U.S.A.
ALAN GUY, P.O. Box, 19033, Nairobi, Kenya.
PETER HAMMERTON, 20, Boultham Avenue, Lincoln.
CHRISTOPHER HAROLD HANSFORD, B.A., 11, London Lane, Bromley, Kent.
VALENTINE BENJAMIN HILL, 31, Washington Terrace, North Shields, Northumberland.
THOMAS ALEXANDER HRUSKA, 293, Riverside Drive, New York 25, N.Y., U.S.A.
MICHAEL DIAS HULL, 33, Manor Road, Teddington, Middlesex.
OSCAR LLOYD KING, A.B., 1340, North Citrus Avenue, Hollywood 28, California, U.S.A.
PETER RALPH KURZHALS, Box 4580, V.A.Tech. Station, Blacksbury, Va., U.S.A.
MICHAEL P. MATEER, 18, Langton Road, Mowbray, Cape Town, South Africa.
TERENCE MOORCRAFT, 54, Dinas Street, Grangetown, Cardiff, Glamorgan.
Professor GIBSON REAVES, Department of Astronomy, University of South California, Los Angeles, Calif., U.S.A.
JOHN ALFRED GEORGE SLATTER, 1, Queens Road, Hr. St. Budeaux, Plymouth.
ARTHUR REGINALD TRICE, B.Sc., A.R.C.S., 258, Daventry Road, Cheylesmore, Coventry, Warwickshire.
PAUL FREDERICK WETTENGEL, 1, The Reddings, Lawrence Street, Mill Hill, London, N.W.7.

The following elections were made at the Council Meeting on 8 August, 1959:

New Fellows.

ARTHUR WILLIAM BEAMENT, Ladram, York Road, Camberley, Surrey.
FRANK BEAMENT, 24, London Road, Camberley, Surrey.
BRIAN LEONARD CLARKSON, B.Sc., Ph.D., "Tolcarne," Moorlands Crescent, Bitterne, Southampton.
DEREK CONWAY, 51, Rodney Road, Walton-on-Thames, Surrey.
ERNEST DICKINSON, 198, Church Road, Willesden, London, N.W.10.
BRIJ NANDAN GUPTA, B.E., M.Sc., c/o Mrs. A. N. Newland, Victoria House, Station Road, Netley Abbey, Southampton.
PETER HOBDAY, 10, Garth Road, Child's Hill, London, N.W.2.
JOHN ROBERT HYDE, c/o Kahn & Co., 541, Windsor Street, Hartford 1, Connecticut, U.S.A.
TADEUSZ STEFAN JARNECKI, 4, Thornton Road, East Sheen, London, S.W.14.
JAMES T. LEE, 4, Simon Dean, Bovingdon, Hemel Hempstead, Hertfordshire.
JAMES OSCAR LEONARD, Jnr., B.S., 13902, Parkland Drive, Rockville, Maryland, U.S.A.
FRANK DEREK MACK, "Carolia," High Street, Yarmouth, Isle of Wight.
Professor ROBERT HUGH MACMILLAN, M.A., University College, Singleton Park, Swansea, Glamorgan.
EUGENE LEWIS PLACE, B.Sc., 141, Butt Lane, Allesley, Coventry.
FRANK B. POLLARD, 2722, Ardmore Avenue, Manhattan Beach, California, U.S.A.
JACK TREVOR ROSE, "Treetops," Duffield Lane, Stoke Poges, Buckinghamshire.
CLIVE STIRLAND, 24, Aubrey Street, Middlesbrough, Yorkshire.
JOHN UNDERWOOD, 15, Princess Close, East Cowes, Isle of Wight.
RICHARD VERE WARDEN, M.S., 18701, Vale Avenue, Santa Ana, California, U.S.A.
GROSVENOR SEARLES WICH, M.S., Ph.D., 45-B, Elsmere Boulevard, Wilmington 5, Delaware, U.S.A.
GEORGE EDWARD WILD, Weir Cottage, Weir Lane, Marshfield, Chippenham, Wiltshire.
ROBERT WILLIAM WRIGHT, Eben-Ezer, Downs Road, Dunstable, Bedfordshire.

Members elected to the Fellowship.

DEREK JOHN CARTWRIGHT, 65, Porlock Avenue, Weeping Cross, Stafford.
CHARLES CLYDE COLEMAN, B.A., 144-D, South Reeves Drive, Beverly Hills, California, U.S.A.
JOHN JAMES KEAR COLWELL, B.Sc., 13, Dale Avenue, Hassocks, Sussex.
PETER FAIRBAIRN, B.Sc., 47, Westbourne Avenue, Walkerdene, Newcastle-on-Tyne, 6.
JACOB WILLIAM HUGHES, B.A., 2030, Athens Avenue, Apartment "L," Boulder, Colorado, U.S.A.
MICHAEL DIAS HULL, 33, Manor Road, Teddington, Middlesex.
DEREK LAWRENCE MELLOR, Graduate I.E.E., 132, Allcroft Road, Hall Green, Birmingham, 11.
DAVID ARTHUR REDDING, 9, Bridge Street, Barrow-on-Soar, Loughborough, Leicestershire.
DONALD WILLIAM THOMPSON, B.Sc., Ph.D., 5514, Corvette Crescent, Vancouver 8, British Columbia, Canada.
HANS BEAT WACKERNAGEL, Ph.D., 103, Pine Hill Road, Bedford, Massachusetts, U.S.A.
ERIC MARSHALL WAINE, 113, Erskine Road, Sutton, Surrey.
PATRICK WALDRON, B.Sc., 19, Orchard Road, Middlesbrough, Yorkshire.
RAYMOND WILLIAM WHITE, 6, Cedar Close, Warlingham, Surrey.
JOSEPH WITKOWSKI, D.Ph., D.Sc., University Observatory, 36, Sloneczna, Poznan, Poland.

New Members.

WILLIAM BARLOW, 7, Ring Drive, Stockport, Cheshire.
LESLIE JOHN BOND, 11, Conybeare Road, Llandaff, Cardiff.
PERCY ARTHUR BRAHAM, 16, Morley Street, Derby.
SIDNEY BRYNE, 14, Egerton Square, Knutsford, Cheshire.
ALFRED BULL, Street Farm, Takeley, Essex.
HUGH DAVID, B.Sc., 2, Sweetbriar Lane, South Street, Epsom, Surrey.
LESLIE GOLLOP, 32, The Greenwood, Guildford, Surrey.
IAN BAIN HILL, 9, Corbiehill Avenue, Edinburgh, 4.
PETER DONALD HOLMES, 56, Argyle Avenue, Palmerston North, New Zealand.
ASGER NAPIER HANSEN, O.B. Muusvej 17, Farum, Denmark.
PETER EDMUND OLDMAN, 52, Woodstock Road, East Park Estate, Wolverhampton, Staffordshire.
GEOFFREY WILLIAM PARSONS, 54, Clavell Road, Liverpool 19, Lancashire.
ROBERT EDWARD ROSS, A.M., 269, Niantic River Road, Waterford, Connecticut, U.S.A.
MELVIN SHAPIRO, M.A.E., 1322, Thompson Drive, Bay Shore, New York, U.S.A.
CHRISTOPHER TILLEY, 4, High Street, Launceston, Cornwall.
LANCE RICHARD PHINEAS WAYMAN, Queen's College, University of Melbourne Carlton N.3, Victoria, Australia.
ALFRED HENRY WHITAKER, 39, Clanricarde Gardens, London, W.2.
RODNEY HERBERT FRANK WOOD, 42, Northcote Road, Southampton.

New Corporate Member.

AVIATION BRANCH, AIR B.P. LTD., B.P. House, Ropemaker Street, London, E.C.2.

The following elections were made at the Council Meeting on 3 October, 1959:

New Fellows.

CHARLES NOEL ADKINS, B.E., 202–1109, North Patrick Henry Drive, Falls Church, Virginia, U.S.A.
EDWARD GEORGE D. ANDREWS, 2, Almond Grove, Newbold on Avon, Rugby, Warwickshire.
Professor DAVORIN BAZJANAC, Zagreb, Gundulićeva 49, Jugoslavia.
RONALD WILLIAM BEVAN, B.Sc., 27 Great Bushey Drive, Totteridge, London N.20.
ALAN GEORGE BRADSHAW, G.I.Mech.E., 37, Bowerfield Crescent, Hazel Grove Cheshire.
Wing Cdr. RALPH BROWN, A.F.R.Ae.S., No. 6, O.M.Q., R.A.F. Wittering, Nr. Peterborough, Northamptonshire.
THOMAS PEDRO BUN, P.O. Box, 6450, São Paulo, Brazil.
WILLIAM HENRY B. CLARKE, A.B., 1243, S. Forest Drive, Arlington 4, Virginia, U.S.A.
WALTER ALFRED CROWLEY, B.Sc., Apt. 2, 1730, Edsall Road, Alexandria, Va., U.S.A.
EDWARD RYANT DYER, Jnr., M.A., Ph.D., 3626, Davis Street, N.W., Washington 7, D.C., U.S.A.
Lt.-Col. JAMES H. FOX, Ph.D., R.R. 11 (Grove City) Englewood, Florida, U.S.A.
JULIUS THOMAS FRASER, B.E.E., 20, Roselle Avenue, Pleasantville, N.Y., U.S.A.
PETER JOHN T. GORLE, G.I.Mech.E., 3, Flexbury Park Road, Bude, Cornwall.
MICHAEL STRACHAN GRIEVE, B.Sc., 8, Woodville Gardens, Ealing, London, W.5.
PEMBROKE J. HART, M.A., Ph.D., U.S.N.C.-I.G.Y., National Academy of Sciences. 2101, Constitution Avenue, N.W., Washington 25, D.C., U.S.A.
WILLIAM FRANK HILTON, Ph.D., D.Sc., A.R.C.S., D.I.C., F.R.Ae.S., Head, Astronautics Section, Advanced Projects Group, Hawker Siddeley Aviation Ltd., Kingston, Surrey.
MICHAEL THOMAS ROBIN HOTSTON, Norton Farm, Norton, Chichester, Sussex.
LESLIE SAMUEL A. JONES, A.R.Ae.S., 745, Woodbridge Road, Ipswich, Suffolk.
ELMOR P. JORDETH, B.S., 2305, Peabody Drive, Falls Church, Va., U.S.A.
CARL CLARENCE KIESS, A.B., Ph.D., 2928, Brandywine Street, N.W., Washington 8, D.C., U.S.A.
WILLIAM DONALD MCCOURTY, B.Sc., 76, Ward Road, Goldthorn Park, Wolverhampton.
RONALD JOHN MITCHELL, 67, Coniston Gardens, Kingsbury, London, N.W.9.
JAMES MELVILLE NORRIS, G.I.Mech.E., 7, Springfield, Littleover, Derby.
Professor KYRILL OGORODNIKOV, Leningrad University, Leningrad, U.S.S.R.
BERNARD PEAVEY, B.E.E., 2804, King Street, Alexandria, Va., U.S.A.
DONALD EARL PERRY, A.B., 1537, South 28th Street, Arlington, Va., U.S.A.
DAVID ROTBART, B.S., 5333, Potomac Avenue, N.W., Washington 16, D.C., U.S.A.
GEOFFREY ROWDEN, 42, Spennithorne Road, Stockton on Tees, Co. Durham.
TADEUSZ RUDENSKI, A.F.R.Ae.S., 92, Elgin Crescent, London, W.11.
FREDERICK JOHN SANSOM, B.A., M.S., 5350, Rexford Road, Dayton 30, Ohio, U.S.A.
BOHDAN JAROSLAV J. SHAK, Hillcrest, Sharnbrook, Bedford.
DONALD ALFRED SHEPHARD, 9, The Hornbeams, Stevenage, Hertfordshire.
NORMAN HERBERT STENNARD, 15, Spanbourn Avenue, Chippenham, Wiltshire.
JOHN KENNETH STERRETT, B.S., M.A., Ph.D., 2321, Jameson Street, S.E., Washington, 21, D.C., U.S.A.
Lt.-Col. VLASTIMIR A. STEVOVICH, M.A., 4200, Cathedral Avenue, N.W., Apt. 415, Washington 16, D.C., U.S.A.
PETER CRESSWELL STOBART, 26, Wychdell, Longmeadow, Stevenage, Hertfordshire.
JOHN WALTON, B.Sc., Ph.D., D.I.C., Grad.R.Ae.S., 124, Cromwell Road, South Kensington, London, S.W.7.
PHILIP JOSEPH WYATT, A.B., M.S., Ph.D., Aeronutronic—A Division of Ford Motor Co., Newport Beach, Calif., U.S.A.

Members elected to the Fellowship.

Fl. Lt. VICTOR COATES APPLETON, 1, Latham Road, Cambridge.
DAVID HENRY GITTINS, 13, Glenferrie Road, St. Albans, Hertfordshire.
THOMAS JACKSON HUDSON, Tudor Lodge, 126 Edgware Way, Edgware, Middlesex.
WILLIAM ALBERT J. KINGSCOTT, "Elm View," Patchway Common, Patchway, Nr. Bristol.
MALCOLM CHARLES METCALFE, 38, Main Street, Heslington, York.
GONZALO J. MORALES, Ave. Simon Planas, Qta., Francis Sta., Monica, Caracas, Venezuela.
ARTHUR COLLIN ROTHERHAM, "Blackamati," Mont au Pretre, St. Helier, Jersey, Channel Islands.
HUGH TANSLEY, 3, The Mount, Wembley Park, Middlesex.

New Associate Fellows.

JOHN TREVOR ABBOTT, 300, Groston Road, Farington Moss, Leyland, Preston, Lancashire.
RONALD BROWN, Hill Court Cottage, Four Elms, Nr. Edenbridge, Kent.
TERRENCE WILLIAM BROWN, 9, Bancombe Road, Somerton, Somerset.
DONALD ROY CULLIFORD, 35, Upper Oldfield Park, Bath, Somerset.
IAN CAMPBELL FLETCHER, B.Sc., D.S.I.R. Radio Research Substation, c/o University of Malaya in Singapore, Singapore, 10.
TREVOR PAUL HELEY, 14, Markham Crescent, Dunstable, Bedfordshire.
ALFRED JONES, 3, Boscombe Drive, Hazel Grove, Cheshire.

LUIGI ANTONIO S. MANSI, 25, Sheriff Road, West Hampstead, London, N.W.6.
GERD NATHAN, 1706, Arlington Boulevard, Falls Church, Va., U.S.A.
PETER HENRY REEVE, Kenya Tea Co. Ltd., Kericho, Kenya Colony.
JOHN JAMES RICHARDSON, G.I.Mech.E., 69, Westwood Drive, Little Chalfont, Amersham, Buckinghamshire.
GEORGE CALVERT VIETH, 605, Westcott Street, Falls Church, Va., U.S.A.
PETER WADDELL, 8, Baluniefield Road, Douglas and Angus, Dundee.
WILLIAM WATSON, 11, Claymores, Stony Hall West, Stevenage, Hertfordshire.

Members elected to Associate Fellowship.

VALENTINE BENJAMIN HILL, 31, Washington Terrace, North Shields, Northumberland.
STANLEY THEO SMITH, Pippins Cottage, Church Hill, Totland Bay, Isle of Wight.
EDWARD JOHN YOUNG, A.B., Box 48, Tuxedo Park, New York, U.S.A.

New Members.

ANTHONY RALPH ANNIBAL, 14, Main Road, Gedling, Nottinghamshire.
HARRY WINSTON ATHERTON, 40, Water Tower View, Hoole Lane, Chester.
GORDON HOWARD BAYES, Stoics House, London Airport, Hounslow, Middlesex.
ERIC JOHN G. BEAUMAN, 13, Charles Crescent, Drymen, Stirlingshire.
PERCY BOWN, 55, Wood Street, Northampton.
LEE COMBS, A.B., LL.B., 264, Tigertail Road, Los Angeles 49, Calif., U.S.A.
PAMELA DREW, 43, Draycott Place, London, S.W.3.
ROBERT WILLARD FARQUHAR, B.S., 9745, Cook Avenue, Oaklawn, Ill., U.S.A.
RODERICK MARK M. FOSTER, B.A., Rose Cottage, Syston Park, Grantham, Lincolnshire.
BARBARA ASTRID GERSHILL, B.Sc., c/o 82–84, Fenchurch Street, London, E.C.3.
CAROLE JEANNE GRAY, 310, Jackson Street, Arlington 1, Va., U.S.A.
JOHN HARMAN, 63, Woking Road, Cheadle Hulme, Cheadle, Cheshire.
DANUTA MARIE HERBERT, B.Sc., 200 Rue St. Jacques, Paris, France.
JAMES WILLIAM HODGE, 14, Calder Street West, Edinburgh 11.
RONALD JAMES KELWAY, 8, St. Johns Park, Blackheath, London, S.E.3.
PATRICK HOWARD KENNEY, M.A., 8 Princes Avenue, Carshalton, Surrey.
MILDRED MARIE LEE, 5832, Paul Street, Sunset Manor, Alexandria, Va., U.S.A.
JAMES GUS LINDERS, 387, St. Paul Street, St. Catharines, Ontario, Canada.
JOAN LEE LEONARD, 13902, Parkland Drive, Rockville, Maryland, U.S.A.
DAVID SWAYNE MACLAUGHLIN, 7, Osborne Drive, Bangor, Co. Down, Northern Ireland.
JOHN ALLEN MARTINA, R.A.F. Hospital Staff, R.A.F. Staging Post, Katunayake, Ceylon.
VALERIE JOAN MATHESON, 4, Denham Drive, Ilford, Essex.
JOHN MCGOVERN, c/o Jones, 51, Oxgangs Avenue, Edinburgh, 13.
JOHN WINTON MCNAB, 13, Hamilton Road, Grangemouth.
ANTHONY CHARLES MILSOM, Churchend, Slimbridge, Gloucestershrie.
DONALD GEORGE MONTGOMERY, 24, Boltons Lane, Harlington, Middlesex.
WILLIAM DAVID MOORE, "Edindoune," Houl Road, Scalloway, Shetland Isles.
ARMANDO SILVESTRI, via Agrigento 3, Roma, Italy.
ALAN WORRALL SOUTHERN, 45, Queens Avenue, Meols, Hoylake, Wirral, Cheshire.
ANTHONY WILLIAM WEBB, Boundary Hall, Tadley, Hertfordshire.
AUSTIN WICKWIRE, 308, West Paseo De Cristobal, San Clemente, Calif., U.S.

The following elections were made at the Council Meeting on 7 November, 1959:

New Fellows.

JOHN DOIG ANDERSON, B.Sc., 27, Ashley Road, Ryde, Isle of Wight.
CHRISTOPHER EDMUND GERVASE BAILEY, M.A., Solartron Industrial Controls Ltd., Victoria Road, Farnborough, Hampshire.
THOMAS LAWRENCE CONNORS, B.A., 1316, Sheehan, Ann Arbor, Michigan, U.S.A.
GORDON BELL MCNAB, 6, Daleside, Upton-by-Chester, Cheshire.
ARNOLD ROY MAXWELL NOTON, B.Sc., Ph.D., 4800, Oak Grove Drive, Pasadena, Calif., U.S.A.

New Associate Fellows.

MALCOLM STANLEY COOPER, The Flat, Long Crendon Manor, Frogmore Lane, Long Crendon, Buckinghamshire.
DONALD ARTHUR LAURIE, 33, Blackmore's Grove, Teddington, Middlesex.
WESLEY O'FERAL PIPES, Jnr., M.S., Ph.D., 1125, Oak Street, Evanston, Illinois, U.S.A.
RONALD STEAD, B.Sc. 9, Greathead Street, South Shields, County Durham.
MARCIA W. WOOSTER, B.S., 2108, Seminary Road, Silver Spring, Maryland, U.S.A.

New Members.

ANTHONY CORDEAUX ALLIN, M.B., Ch.B., Bartley Grange, Bartley, Southampton.
ELSIE CROCKER, 25, Beverley Avenue, Canvey Island, Essex.
GEORGE ALBERT HOPE, 190, Conway Crescent, Greenford, Middlesex.
JOIE PIERCE JONES, 1110, Sycamore Street, Abilene, Texas, U.S.A.
PETER MANCINI, 32, Chaucer Road, Newtown, Gt. Yarmouth, Norfolk.
IAN LEONARD MCLAUGHLIN, 9, Auburn Avenue, Myrtle Bank, c/o Parkside P.O., South Australia, Australia.
DAVID S. MERRILEES, M.A., 267, Mabery Road, Santa Monica, California, U.S.A.
MARK PATTERSON, 6, Rydal Road, Lemington, Newcastle-on-Tyne, 5.
KENNETH WARREN RICHARDSON, 16, Clifton Road, Parkstone, Dorset.
GERRARD ALEXANDER WALMISLEY, Berryfields Gated Way, off Bicestor Road, Nr. Aylesbury, Buckinghamshire.
JOHN BRIAN WILSON, 30, Lodore Road, South Shore, Blackpool, Lancashire.

The following elections were made at the Council Meeting on 5 December, 1959:

New Fellows.

FLT. LT. SAMUEL LEWIS BUGG, A.F.R.Ae.S., Officer's Mess, R.A.F. Technical College, Henlow, Bedfordshire.
RICHARD JOHN CONNER, B.S., 307, Holliston Street, Medway, Mass., U.S.A.
SIR RONALD HERBERT GARVEY, K.C.M.G., K.C.V.O., M.B.E., M.A., Government House, Douglas, Isle of Man.
ERNEST WILLIAM STILL, B.Sc., Ph.D., F.R.Ae.S., "Penmyarth," 63, The Park, Yeovil, Somerset.
WILLIAM D. YOUNG, B.S., c/o Space Tech. Labs., Jodrell Bank, Lower Withington, Cheshire.

Members elected to the Fellowship.

JAMES COZBY BYRD, Jnr., B.S., M.A., 510, Fairfax Avenue, Nashville 12, Tenn., U.S.A.
KARL ANTHONIE MARTIN, 70, Queens Road, New Tredegar, Monmouthshire.
ROBERT EDWARD ROSS, A.M., 269, Niantic Road, Waterford, Conn., U.S.A.

New Associate Fellows.

DOUGLAS HENRY FRAME, P.O. Box 14350, Nairobi, Kenya.
RAYMOND FREDERICK MURTON, 31, Harvard Court, Honeybourne Road, London, N.W.6.
ALAN CHARLES PAGE, B.Sc., 288, King Street, Brynmawr, Breconshire.

Member elected to Associate Fellowship.

JOHN HARMAN, 63, Woking Road, Cheadle Hulme, Cheadle, Cheshire.

Member elected to Senior Membership.

JOHN EDWARD GERALD BYRNE, 132, Holland Road, Kensington, London, W.14.

New Members.

KENNETH IAN T. COATES, "Yew Tree Cottage," Lindow, Alderley Edge, Cheshire.
GEORGE HEIDT DOBBS, Jnr., 2141, Minnesota Avenue, Winter Park, Florida, U.S.A.
DAVID MICHAEL FULTON, All Saints Vicarage, Hampton Road, Forest Gate, London, E.7.
THOMAS IVOR JONES, 253, School Road, Crookes, Sheffield 10, Yorkshire.
EARLE WESLEY RICHARDSON, Jnr., 3109, 44th Street, N.W., Washington 16, D.C., U.S.A.
MARY PATRICIA THOMPSON, Linton, Astley Bank, Darwen, Lancashire.

The following elections were made at the Council Meeting on 9 January, 1960:

New Fellows.

HELMUT G. L. KRAUSE, Ph.D., 208, Lincoln Street, S.E., Huntsville, Ala., U.S.A.
ROBERT JOSH LEE, M.A., 6629, Williston Place, Apt. 101, Falls Church, Va., U.S.A.

New Associate Fellows.

GEORGE FREDERICK SCRIMSHAW, Enborne Rectory, Enborne, Newbury, Berkshire.
HENRY PRATT CATE, Jnr., A.B., Box 4–1481, Anchorage, Alaska.

Members elected to Associate Fellowship.

RONALD LESLIE CLARKE, 21, Manston Drive, Bishops Stortford, Hertfordshire.
JOSEPH JOHN EDWARD ALFRED COULTHARD, B.Sc., 7, Montrose Avenue, Wakefield, Mass., U.S.A.
HUGH DAVID, B.Sc., 2, Sweetbriar Lane, South Street, Epsom, Surrey.
ROBERT WILLARD FARQUHAR, B.S., 9745, Cook Avenue, Oaklawn, Ill., U.S.A.
BERT LEWIS, 4, Queensway, Ashton on Ribble, Preston, Lancashire.

Members elected to Senior Membership.

VERNON STANLEY BOXALL, Flat 1, "Shirwood," 25, Harvey Road, Guildford, Surrey.
WALTER ERNEST BRIDGE, *69a*, Ebury Street, London, S.W.1.
STANLEY GEORGE CAULKETT, Fairview Lodge, Fairview Gardens, Leigh on Sea, Essex.
JOHN MICHAEL COCKSEDGE, 51, Wigan House, Warwick Grove, London, E.5.
GEORGE LESLIE COOPER, 3, Eton Road, Orpington, Kent.
DAVID JOHN DAVIES, 21, Tewson Road, Plumstead, London, S.E.18.
ROBERT JOSEPH FARNON, "La Falaise" St. Martins, Guernsey, Channel Islands.
GERALD BARTON HALL, 57, Halstead Road, Winchmore Hill, London, N.21.
ARTHUR CLIFFORD HOATH, Flat 5, Eastry Court, Eastry, Nr. Sandwich, Kent.
Sqn. Ldr. MIROSLAV ANTONIN LISKUTIN, D.F.C., A.F.C., 15, Watchester Avenue, Ramsgate, Kent.
STANLEY ALFRED MOTT, 2049, Honeywell Avenue, Ottawa 3, Ontario, Canada.
LAURENCE THOMAS O'CALLAGHAN, 4, Svir Road, S.C., Inchicore, Dublin, Eire.
HARVEY BERNARD PATMORE, Fairmile House, The Fairmile, Cobham, Surrey.
JULIEN PERIDIER, 16, Rue Cassette, Paris vi, France.
ARTHUR WILLIAM ROBERTS, 29, Warner Avenue, Pogmoor, Barnsley, Yorkshire.
TIMOTHY JOHN NICOLL ROWELL, 80, Kensington Park Road, London, W.11.
ALFRED JOSEPH SCORDING, 222, Exeter Road, Harrow, Middlesex.
PETER HEADLEY SELLERS, 401, West Price Street, Philadelphia 44, Pa., U.S.A.
RONALD SMITH, Plot 200, Hazel Garth, Stockton Lane, York.
TREVOR BRANT SMITH, 15, Coalway Road, Wolverhampton.
AMBROSE JOEL WHITE, 184, Alcester Road, Stratford-on-Avon, Warwickshire.

New Members.

JULIAN KENNETH GOSDEN, 13, The Common, Ashtead, Surrey.
HAROLD WALTER HAUGAN, M.Sc., Ph.D., 1396, Smith Street, Birmingham, Michigan, U.S.A.
MICHAEL KAYE, 8, Eastbourne Road, South Tottenham, London, N.15.
ROBERT WILLIAM MILKEY, 8027, Aberdeen Road, Bethesda 14, Maryland, U.S.A.
MIHRAN MIRANIAN, 4729–47th St. N.W., Washington 16, D.C., U.S.A.
ERNEST GEOFFREY PRIESTLEY, 6, Lynden Avenue, High Busy Lane, Windhill, Shipley, Yorkshire.
JOHN RUDMAN, 6, Warren Rise, Frimley, Nr. Aldershot, Hampshire.

PERSONALITIES

Below are given some biographical details of five Members of Council who first assumed office this year.

Mr. John E. Allen

John Elliston Allen was born in Stoke Newington, London, in 1921, and educated at Northampton Engineering College, University of London, from 1937 to 1941. He graduated with First-Class Honours in Aeronautical Engineering.

Mr. Allen joined the Aerodynamics Department of the Royal Aircraft Establishment, Farnborough, and later transferred to the Marine Aircraft Experimental Establishment at Helensburgh and Felixstowe. He returned to Farnborough in 1950 (to the Armaments Department), becoming a Principal Scientific Officer in 1953.

In 1954, Mr. Allen joined A. V. Roe & Co., Ltd., as Head of the Aerodynamics, Projects and Assessment Department, Weapons Research Division.

Mr. Allen's interest in spaceflight was aroused in 1939, and he began lecturing on the subject to a wide variety of audiences in 1950. His particular fields of interest now are the technological aspects of space vehicle design and construction, particularly where these have parallels with modern aeronautical practice.

He was awarded the J. E. Hodgson prize for his paper "From Aviation to Astronautics," given to the Royal Aeronautical Society in 1958.

Mr. Maurice Brennan

Maurice Brennan was born on 16 April, 1913, at Muswell Hill, London, and educated at St. Mungo's Academy, Glasgow, and Glasgow University, where he obtained the B.Sc. degree with Honours in Mechanical Engineering. He also took a Ground Engineer's course at Renfrew Aerodrome and obtained a Private Pilot's "A" licence in June, 1931.

After training under the Blackburn Aircraft university apprentice scheme, Mr. Brennan joined Hawker Aircraft as a junior technician in October, 1934, and worked on the Hurricane P.V. monoplane and subsequent aircraft.

In January, 1937, Mr. Brennan joined Saunders Roe as a stressman, transferring to the Aerodynamics Department in 1939, and to the Projects Department in 1947. In 1948 he became Technical Assistant to Sir Arthur Gouge, and with the acquisition of the Cierva Co. he was appointed Assistant Chief Designer in charge of Saunders Roe's Helicopter Division at Eastleigh. During this period he was responsible for stress and aerodynamic work on the Lerwick twin-engine military flying boat, the Short/Saunders Roe Shetland, and the Saunders Roe S.R. A1.

Mr. Brennan became Deputy Chief Designer of the complete Saunders Roe undertaking in April, 1951, and was responsible for work on the Princess flying boat. In October, 1952, he was promoted to Chief Designer; in this post he was responsible for the S.R. 3 rocket-*cum*-jet interceptor and for the cancelled S.R. 177 development aircraft. He was also responsible for the design and development of the Black Knight rocket test vehicle, under Royal Aircraft Establishment direction.

Other projects with which he was connected were the design and development of the Canadian hydrofoil craft *Bras d'Or*, and finally the initial research and design work on the Hovercraft and associated principles.

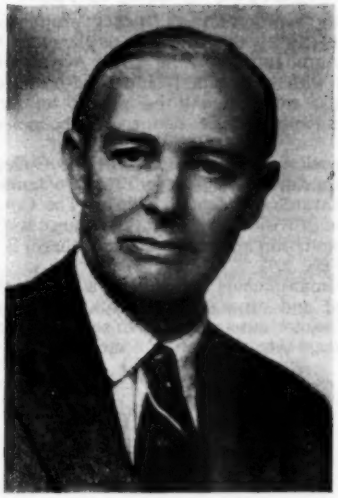
Mr. Brennan resigned from Saunders Roe in April, 1959, and joined Vickers Ltd. in the following month as Assistant Chief Engineer, Military Projects. He served in this position until December, 1959. He joined Folland Aircraft Ltd., Hamble, Southampton, in January, 1960, as Director and Chief Engineer.

Mr. A. H. S. Candlin

Alfred Hugh Stanton Candlin was born in 1911 and educated at Edinburgh University, where he graduated with the degree of B.Sc.(Tech.Chem.).

Since graduating, Mr. Candlin has been concerned with chemical engineering, metallurgy, shipbuilding and nuclear energy. Much of his experience has been abroad, including the Far East, India (where he was an officer of the Indian Ordnance Service), and after the war, in Germany.

More recently, Mr. Candlin held a civil service appointment in which he was seconded by the Ministry of Defence to the



Foreign Office. He is now Managing Director of Astronautical Development Group Ltd. and is also engaged in metallurgical and chemical engineering consulting work.

Sqn.-Ldr. M. N. Golovine

Michael N. Golovine was born in 1903 and educated at the City and Guilds (Engineering) College, London, from which he graduated with the A.C.G.I. diploma.

After serving an apprenticeship with Panhard & Levassor, in 1925 Mr. Golovine joined the Paris subsidiary of Rolls-Royce, Ltd. He was Continental Representative of the Aero Engine Division of Rolls-Royce, Ltd. from 1931 until 1940, when he volunteered to the Technical Branch of the R.A.F.V.R. In 1936 he was co-author of "Air Strategy" and in 1938 he wrote "Views on Air Defence."

Mr. Golovine served in the R.A.F.V.R. until 1944, specializing in enemy aircraft and weapon development, with particular reference to the V-1 and V-2 weapons. He was awarded the U.S. Bronze Star.

After the war Mr. Golovine returned to industry, serving as Technical Representative, Armstrong Siddeley Motors, Ltd., 1945-46; Sales Co-ordination Manager, Hawker Siddeley Group, 1947-50; Aero Sales Director, Armstrong Siddeley Motors, Ltd., 1950-55. Since June, 1955, he has been Managing Director of A.T.S. Co. Ltd. (the Evaluation Market Research and Forward Thinking Unit of Hawker Siddeley Aviation, Ltd.).

Mr. Golovine was appointed a Member of the Order of the British Empire on 2 June 1943.

Mr. N. R. Nicoll

Norman Robson Nicoll was born in 1919 and educated at Queen Mary's Grammar School, Walsall, and Birmingham College of Art. He joined the Society in 1937.

Mr. Nicoll served in the Royal Navy from 1940 to 1946, being engaged on radar. After the war he returned to Birmingham to study science and art and to qualify for the teaching profession.

After qualifying, he took up an appointment on the staff of the Metallurgy Department, Staffordshire County Technical College, Wednesbury. In 1955, he accepted his present post of Lecturer in the Design and Use of Materials, at Tamworth College and Lichfield Art School.

After organizing the formation of the Midlands Branch of the Society in 1949, Mr. Nicoll served as Branch Chairman for the first three years. He was progenitor of the Society's permanent travelling exhibition and is the present Chairman of the Exhibits Group. His particular fields of interest in astronautics are physiological and psychological aspects and their attendant design problems. His other interests are archaeology, gemmology, music and sculpture.

JOINT ACTIVITIES

Symposium on Rocket and Satellite Instrumentation

A one-day symposium on rocket and satellite instrumentation is being organized jointly by the British Interplanetary Society and the Society of Instrument Technology. Emphasis will be placed on work actually being undertaken, or projected, within the United Kingdom during 1960.

The Symposium is to take place at Manson House, 26 Portland Place, London, W.1, on Thursday, **1 September, 1960.** The papers at present scheduled for presentation include:

The British Satellite Programme, by M. O. Robbins.

A Design Study on a Communication Satellite, by B. V. Somes-Charlton.

An Analyser for Rocket Recording, by Dr. W. R. Beakley.

Transducers for Motor Testing, by D. S. Dean.

An Experiment to be Carried Out in a British Satellite, by Dr. A. P. Willmore.

The Measurement, Transmission and Recording of Data in the Skylark, by Dr. E. B. Dorling.

These titles are provisional, and one additional paper may be included, but it is intended to restrict the total number of papers to approximately eight, in order to leave adequate time for discussion. The object of the Symposium is to indicate the fields of new scientific knowledge which have been opened up by experiments in the upper regions of the atmosphere and in outer space, and to describe the kind of instrumentation which has either already been used, or will be required for future research.

Preprints of the principal papers will be provided to all symposium participants, who will be charged a Conference Fee of two guineas (£2 2s. 0d.); this will also cover the provision of light refreshments during the morning and afternoon sessions. A limited number of *bona fide* students, receiving full-time education will be admitted for a reduced fee of £1. In view of the limited accommodation, early application is advisable. Librarians and others who do not wish to attend the meetings, but wish to obtain sets of preprints may obtain these on payment of a fee of £1.

A registration form for the Symposium is enclosed in this issue of the *Journal*. On completion, it should be returned with the necessay fee to: The Secretary, British Interplanetary Society, 12 Bessborough Gardens, London, S.W.1. Cheques and Money Orders should be made payable to the British Interplanetary Society.

Symposium on Space Navigation

A one-day Symposium on Space Navigation is being organized jointly by the British Interplanetary Society and the Institute of Navigation. It will comprise about six papers related to a particular mission, probably the early manned exploration of the Moon. It will be held in the Lecture Theatre of the Royal Geographical Society, 1 Kensington Gore, London, S.W.7, on Friday, **18 November, 1960.**

Further announcements concerning the papers to be presented, conference fees, etc., will appear in the *Journal*. Members and others who are likely to attend should inform the Secretary as soon as possible.

Symposium on Rocket Propulsion

A two-day symposium on rocket propulsion is being organized jointly by the British Interplanetary Society, the College of Aeronautics and the Royal Aeronautical Society. It will deal with both liquid- and solid-propellent rockets, and particular emphasis will be placed on British work. Short papers from younger scientists and technologists will be welcomed.

The symposium is to take place at the College of Aeronautics, Cranfield, from 2 p.m. on Friday, **6 January, 1961**, to 6 p.m. on Saturday, **7 January, 1961.** The Conference Fee (covering the provision of preprints, entrance to the meetings and accommodation and meals at the College) is expected to be about £5-£6.

Future announcements will give particulars of the papers to be presented and other arrangements, but those likely to attend the Symposium are invited to send a preliminary notification of their intention to the Secretary.

DIARY

The Society

28 April. "High Altitude Chambers and Pressure Suits," by Dr. E. W. Still (Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1, at 7 p.m.).

6 May. Visit to de Havilland Engine Co. Ltd., Hatfield, Hertfordshire (Tickets required).

15 July. Fifteenth Annual General Meeting. (Kent Room, Caxton Hall, Caxton Street, London, S.W.1, at 6.30 p.m.).

Branches and Informal Groups

29 April. Provisional Scottish Branch. Annual General Meeting.

14 May. Midlands Branch. Ninth Annual Business Meeting (Birmingham and Midland Institute, Paradise Street, Birmingham 1, at 6.30 p.m.).

May. Washington Metropolitan Branch. Three-day Astronautical Exposition, with business and anniversary meeting (Georgetown University).

International Astronautical Federation

15-20 August. Eleventh International Astronautical Congress (Stockholm, Sweden). **Other Bodies.**

21 April. Royal Aeronautical Society (Astronautics and Guided Flight Section). "On Reducing the Costs of Space Research," by J. E. Allen (Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1, at 6 p.m.).

13 April. British Institution of Radio Engineers (Computer Group). "Guided Weapon Control," by F. R. J. Spearman (London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, at 6.30 p.m.).

21-27 July. International Federation for Medical Electronics and **Institution of Electrical Engineers (Electronics and Communications Section).** Third International Conference on Medical Electronics; includes session on medical electronics in space research (Olympia, London).

26-28 August. German Rocket Society. Ninth Symposium on Rockets and Spaceflight (Maschsee Gaststatten, Hannover, Germany).

29-30 September. Institute of Biology. Symposium on Biological Aspects of Space Exploration.

ASTRONAUTICAL ABSTRACTS

Edited by J. HUMPHRIES and J. FOLEY

1960 PART 7

A list of abbreviations of titles of journals was inclued in the 1954 index and addenda have been publish ed in subsequent issues of the *Journal*. A further addendum is given below:

Aero. Purchasing.	Aeronautical Purchasing.
Aero-Space Engng.	Aero-Space Engineering (*supersedes* Aeronautical Engineering Review).
Amer. Geophys. Union Trans.	American Geophysical Union Transactions.
Amer. Machinist.	American Machinist.
Bell. Labs. Record.	Bell Laboratories Record.
Canad. Mining J.	Canadian Mining Journal.
Chem. Engng.	Chemical Engineering.
Control Engng.	Control Engineering.
Convair Sci. Res. Lab.	Convair Science Research Laboratory.
Electron. Ind.	Electronic Industries.
Electron. Ind. and Tele-Tech.	Electronic Industries and Tele-Tech.
Gen. Electric Rev.	General Electric Review [U.S.A.].
IGY Bull.	IGY Bulletin.
Industr. Labs.	Industrial Laboratories.
Industr. Photog.	Industrial Photography.
Inst. Aero. Sci. Prepr.	Institute of Aeronautical Sciences Preprint.
Inst. Radio Engrs. Proc.	Institute of Radio Engineers Proceedings.
Med. Rabot.	Meditsinskii Rabotnik.
Midwest Engr.	Midwest Engineer.
Petrol. Engr.	Petroleum Engineer.
Phys. Rev. Letters.	Physical Review Letters.
Plastics Techn.	Plastics Technology.
Power Engng.	Power Engineering.
Proc. Instn. Elect. Engrs.	Proceedings of the Institution of Electrical Engineers.
Progr. Theoret. Phys.	Progress in Theoretical Physics.
Soc. Automot. Engrs. Prepr.	Society of Automotive Engineers Preprint.
Soc. Mot. Pict. Televis. Engrs. J.	Society of Motion Picture and Television Engineers Journal.
Southern Res. Inst.	Southern Research Institute.
Sperry Engng. Rev.	Sperry Engineering Review.
Stanford Res. Inst.	Stanford Research Institute.
Univ. Illinois, Dept. Physiol.	University of Illinois, Department of Physiology.
U.S.A.F. Aeromed. Field Lab.	U.S.A.F. Aeromedical Field Laboratory.
Westinghouse Engr.	Westinghouse Engineer.

2—PHYSICS

.1 *General*

(1448) **Testing the general theory of relativity with Earth satellites.** F. Winterberg. *Raketenbrief*, **6**, 4–11 (*May–June*, 1958). (*In German.*) (11 *refs.*)

(1449) **Utilization of artificial Earth satellies for the re-check of the general theory of relativity.** V. L. Ginzburg. *Uspekikh Fizicheskikh Nauk*, **63** (1a), 119–22 (*Sept.*, 1957). (*In Russian.*) [See also abs. no. 382, *J.B.I.S.*, **16**, 493 (*July–Aug.*, 1958.]

.2 *Gravitation*

[*See also* abstract no. 1647]

(1450) **Clock paradox and the physics of discontinuous gravitational fields.** C. B. Leffert and T. M. Donahue. *Amer. J. Phys.*, **26** (8), 515–23 (*Nov.*, 1958). A discussion of the free clock as observed from the frame of the accelerated clock, and inference concerning the acceleration of particles in a time-variant gravitational field.

.4 *Light*

(1451) **The artificial satellite and the relativistic red shift.** A. Das. *Progr. Theoret. Phys.*, **18**, 554–5 (*Nov.*, 1957).

.7 *Cosmic Radiation*

(1452) **Satellite radiation sweeper proposed.** D. A. Anderton. *Aviation Wk.*, **69** (9) (1 *Sept.*, 1958). Report of 9th I.A.F. Congress at Amsterdam.

(1453) **"Radiation belt" and trapped cosmic-ray albedo.** S. F. Singer. *Phys. Rev. Letters*, **1**, 171–3 (1 *Sept.*, 1958). Letter. (2 *refs.*)

(1454) **Trapped albedo theory of the radiation belt.** S. F. Singer. *Phys. Rev. Letters*, **1**, 181–3 (1 *Sept.*, 1958). Letter. (8 *refs.*) Erratum in *Phys. Rev. Letters*, **1**, 300 (15 *Oct.*, 1958).

(1455) **Pioneer indicates restricted radiation.** E. Clark. *Aviation Wk.*, **69** (16), 30–3 (20 *Oct.*, 1958). Discussion of preliminary results from Pioneer lunar probe firings of 17 August and 11 Oct., 1958.

(1456) **Radiation belt explored by Army's Pioneer III probe.** E. Clark. *Aviation Wk.*, **69** (24), 28–31 (15 *Dec.*, 1958). Description of launching of 6 Dec., 1958, which failed to reach the vicinity of the Moon because of premature emptying of one propellent tank.

.8 *Other Upper Atmosphere Phenomena*

(1457) **A method for the determination of the vertical ozone distribution from a satellite.** S. F. Singer and R. C. Wentworth. *J. Geophys. Res.*, **62**, 299–308 (*June*, 1957).

(1458) **Meteorological measurements from a minimum satellite vehicle.** S. F. Singer. *Amer. Geophys. Union Trans.*, **38**, 469–82 (*Aug.*, 1957).

(1459) **Manual on rockets and satellites.** ed. L. V. Berkner *et al.* 508 pp., $25.00, £8. *Pergamon Press, N.Y. and London* (1958). Book. Special communication of the International Geophysical Year.

(1460) **The world in space. The story of the I.G.Y.** A. Marshack. 176 pp. *Nelson, New York* (1958). Book.

(1461) **Ionospheric studies using Earth satellites.** *IGY Bull.*, **7**, 11–16 (*Jan.*, 1958).

(1462) **The structure of our space.** V. Hlavatý. *Aero. Engng. Rev.*, **17** (4), 25–9 (*April*, 1958). Describes the problem of the mathematical description of the properties of space.

(1463) **I.G.Y. research into space continues.** M. Yaffee. *Aviation Wk.*, **68** (24), 153, 155–6, 158–9 (16 *June*, 1958). There is still an enormous scope for investigation by rocket-launched instruments of the properties of the upper atmosphere and near space. Some projects are discussed.

(1464) **Probing the upper atmosphere.** J. C. Holmes and C. Y. Johnson. *Anal. Chem.*, **30** (9), 19A–22A, 24A, 26A, 28A, 30A, 32A, 34A (*Sept.*, 1958).

(1465) **Scale height of the upper atmosphere.** C. H. Bosanquet. *Nature*, **182**, 1010–1 (11 *Oct.*, 1958). Letter. (1 *ref.*)

3—CHEMISTRY AND MATERIALS

.1 *General*

(1466) **Problems encountered in the use of liquid oxygen.** P. L. Castron. *Soc. Automot. Engrs. Prepr.* 238, 4 pp. (*Oct.*, 1957).

(1467) **Nonmetallic material compatibility with liquid fluorine.** H. G. Price and H. W. Douglass. *N.A.C.A. Res. Memo. E.*57G18, 7 pp. (*Oct.* 1957).

(1468) **The useful heat capacity of several materials for ballistic nose-cone construction.** J. R. Stalder. *N.A.C.A. Tech. Note* 4141, 19 pp. (*Nov.*, 1957). Copper, Inconel-X and graphite are considered, copper giving the heaviest solution.

(1469) **Now into the space age! Temperatures up to 30,000° F. are endured by new combinations of materials.** *Modern Plastics*, **35**, 105–110, 218–220 (*June*, 1958).

(1470) **Pumps or pressurised gas for LOX handling?** E. E. Lindros. *Space-Aeronautics*, **30** (5), 38–43 (*Nov.*, 1958). A pump engineer looks at the problem of transferring liquid oxygen.

.2 *Chemistry*

[*See also* abstract no. 1622]

(1471) **Prediction of the explosive behavior of mixtures containing hydrogen peroxide.** E. S. Shanley and J. R. Perrin. *Jet Propulsion*, **28**, 382–8 (*June*, 1958).

(1472) **Preparation and properties of unsymmetrical dimethylhydrazine.** W. G. Strunk. *Chem. Engng. Progr.*, **54** (7), 45–8 (*July*, 1958). Preparation, physical and chemical properties, storage and handling, materials of construction, toxicity and uses. (7 *refs.*)

.3 *Metallurgy*

[*See also* abstracts nos. 1619, 1620, 1621 and 1623]

(1473) **Electroplating is an important step in the construction of a man-made satellite.** G. W. Grupp. *Metal Finishing*, **55**, 40–4 (*July*, 1957).

(1474) **The coatings that go on the satellite.** G. H. Hass. *Magazine of Magnesium*, 4–5 (*Aug.*, 1957).

(1475) **Gold plating of magnesium.** *Electroplating*, **10**, 319–21 (*Oct.*, 1957). Vanguard construction detail.

(1476) **Titanium in rockets and missiles.** S. Abkowitz. *Light Metal Age*, **16**, 15 (*April*, 1958).

(1477) **Look at metalworkings space markets.** *Steel*, **142**, 60–1 (28 *April*, 1958).

(1478) **Materials for a space traveller.** R. A. Jones. *Metal Progr.*, **74**, 78–82 (*July*, 1958).

(1479) **Today's alloys adequate for missile skins.** M. Yaffee. *Aviation Wk.*, **69** (9), 37–43 (1 *Sept.*, 1958). Review of high-temperature structural materials.

.4 *Refractories*

(1480) **Ceramics in first U.S. satellite launching; Norton company's Rokide ceramic coating.** *Amer. Ceram. Soc. Bull.*, **37**, 204 (15 *April*, 1958).

(1481) **Investigation of ceramic materials in a laboratory rocket motor.** J. F. Lynch, J. F. Quirk and W. H. Duckworth. *Amer. Ceram. Soc. Bull.*, **37**, 443–5 (15 *Oct.*, 1958).

.5 *Plastics*

[*See also* abstract no. 1615]

(1482) **Reinforced plastics in outer space.** ed. H. T. Douglas. *Plastics Techn.*, **4**, 62 (*Jan.*, 1958).

(1483) **Asbestos-phenolics aid rocket and missile flight.** D. V. Rosato. *Plastics World*, **16**, 4–6 (*April*, 1958).

4—BIOLOGY AND MEDICINE

.1 *General*

(1484) **Inhabited universe.** K. W. Gatland and D. D. Dempster, 182 pp., $3.95, *McKay, N.Y.* (1958). 21s., *Wingate, London* (1957). $3.00, *Smithers and Bonellie, Toronto* (1957). Book.

(1485) **Human factors research and development program for a manned satellite.** J. P. Henry *et al. A.R.D.C. Tech. Rept.* 57–160 (*Oct.*, 1957).

(1486) **A valuable contribution to the mastering of interplanetary flight.** *Med. Rabot.*, (93), 4 (19 *Nov.*, 1957). (*In Russian.*)

(1487) **Space pioneer: scientists test men and materials for future rocket flights; some human problems.** *Wall Street J.*, 1, 13 (4 *Dec.*, 1957).

(1488) **Man and cosmos.** A. Aleksandrov. *Med. Rabot.*, (105), 3 (31 *Dec.*, 1957). (*In Russian.*)

(1489) **Space pilots.** W. Ley. 44 pp., $1.00 and $2.25. *Guild Press, N.Y.* (1958). Juvenile book.

(1490) **Men, rockets and space rats.** L. Mallan. 336 pp., $5.95, *Messner, N.Y.*, $7.00, *Copp Clark Co., Toronto* (1958). Book, new edition.

(1491) **The environment of space in human flight.** C. A. Berry. *Aero. Engng. Rev.*, **17** (3), 35–8, 60 (*March*, 1958). A review of current knowledge of the problems of oxygen supply, ambient pressure, cosmic and solar radiation, weightlessness and confined conditions. (15 *refs.*)

(1492) **Interrelations of space medicine with other fields of science.** H. Strughold. *Aero. Engng. Rev.*, **17** (4), 30–2, 37 (*April*, 1958). A consideration of the environment of space, movement to, through and back from this environment, and the time factor in space operations.

(1493) **Medicine paces man's flight in space.** C. Lewis. *Aviation Wk.*, **68** (24), 105–6, 108–11, 113–5 (16 *June*, 1958). Discusses medical interest in weightlessness, protection from accelerations, necessities of life in space and communications.

(1494) **Space cooling system demands reliability.** R. Sweeney. *Aviation Wk.*, **69** (18), 54, 59 (3 *Nov.*, 1958). Report of papers on space capsules, environment for crew, crew safety, and aerodynamic stability.

(1495) **Space medicine.** J. Billingham. *Nature*, **182**, 1645–6 (13 *Dec.*, 1958). Proceedings of B.I.S. Space Medicine Symposium, 16–17 October, 1958.

(1496) **Much study must precede man in space.** D. Flickinger. *Aviation Wk.*, **69** (26), 38–41 (29 *Dec.*, 1958). Problems requiring study are the radiations of space, communications, and selection of psychologically suitable crew members.

.2 *Botany*

(1497) **The culture of algae.** P. Edwards. Part of *Report on Engineering Biotechnology of Handling Wastes from a Closed Ecological System. New York University, College of Engineering.* (1958).

(1498) **Food from algae: a review of the literature.** J. Lavery and R. G. Tischer. *Quartermaster Food and Container Institute or the Armed Forces (USA), Library Branch Bulletin No.* 1 (1958).

.3 *Zoology*

(1499) **Soviets recover research rocket dogs.** *Aviation Wk.*, **69** (18), 61, 63 (3 *Nov.*, 1958). Report of Russian rocket experiments using dogs in firings to 280 miles' altitude.

(1500) **Mice survive Thor-Able re-entry.** *Aviation Wk.*, **69** (22), 57, 59 (1 *Dec.*, 1958). Pictures and description of mouse-carrying capsule.

.4 *Anatomy and Physiology*

[*See also* abstract no. 1781]

(1501) **Foods for the spaceman.** J. H. Kilbuch. *Food Technology*, **11** (7), (1957).

(1502) **Space satellite crew to subsist on frozen foods.** W. Ley. *Quick Frozen Foods* (*Nov.*, 1957).

(1503) **Closed cycle biological systems for space feeding.** M. C. Brockmann, A. S. Henrick, G. W. Kurtz and R. G. Tischer. *Studies in Food Science and Technology.* 2. *Feeding Men during Space Flights, Inst. of Food Technologists* (28 *May*, 1958). **Pt. I. Systems 1 and 2**, 22–27 (24 *refs.*). **Pt. II. System 3**, 27–31 (11 *refs.*)

(1504) **Feeding crews in air vehicles of the future.** B. Finkelstein. *Studies in Food Science and Technology.* 2. *Feeding Men during Space Flights, Inst. of Food Technologists*, 18–21 (28 *May*, 1958). (6 *refs.*)

(1505) **Nutrition in space operations.** J. G. Gaume. *Studies in Food Science and Technology.* 2. *Feeding Men during Space Flights, Inst. of Food Technologists*, 6–8 (28 *May*, 1958). (12 *refs.*)

(1506) **Nutrition in space flight.** D. G. Simons. *Studies in Food Science and Technology.* 2. *Feeding Men during Space Flights, Inst. of Food Technologists*, 9–14 (28 *May*, 1958).

(1507) **Present capabilities and future needs for space feeding.** A. A. Taylor. *Studies in Food Science and Technology.* 2. *Feeding Men during Space Flights, Inst. of Food Technologists*, 15–17 (28 *May*, 1958). (12 *refs.*)

.6 *Pathology*

(1508) **Epitome of space medicine.** *U.S.A.F. School of Aviation Medicine, Air University, Randolph A.F.B., Texas* (1957). Book. Reprints of 41 reports.

(1509) **Some observations on orientation and illusions when exposed to sub- and zero-gravity.** G. J. D. Schock. *Univ. Illinois Dept. Physiol.* (1957). Doctor's thesis.

(1510) **Physio-pathological factors in the use of rockets as a means of transportation.** R. Grandpierre and P. Bouverot. *Concours Médical*, **80**, 265–7, 269–70 (1958). (*In French.*)

(1511) **Sensory reactions related to weightlessness and their implications to space flight.** G. J. D. Schock. *U.S.A.F. Aeromed. Lab., U.S.A.F. Missile Development Center*, TN 58–6 (1958).

5—AVIATION AND AERODYNAMICS

.2 *Aerodynamics*

[*See also* abstract no. 1564]

(1512) **Exit and re-entry problems.** G. V. Bull, K. R. Enkenhus and. G. H. Tidy. *Inst. Aero. Sci. Prepr.* 759, 11 pp. (*Oct.*, 1957).

(1513) **Vertical re-entry of very lightweight bodies into the Earth's atmosphere.** R. D. Linnell. *Convair Sci. Res. Lab. RN*9, 30 pp. (*Oct.*, 1957). Determination of the body velocity using rough approximations, an analytical method, and numerical integration. It is found that maximum deceleration increases linearly with increasing release altitude and occurs at around 250,000 ft. The temperature reached by external surfaces increases rapidly as the release altitude is increased.

(1514) **Hypersonic flight and the re-entry problem.** H. J. Allen. *J. Aero. Sci.*, **25** (4), 217–29, 262 (*April*, 1958). This paper leads from conventional aircraft to the hypersonic glider and the skip-rocket. Their propulsion engines are compared, the problems of heating and stability of the hypersonic vehicles are discussed. (17 *refs.*)

(1515) **Magnetic field effects on low shock stand-off distance.** R. W. Ziemer and W. B. Bush. *Phys. Rev. Letters*, **1**, 58–9 (15 *July*, 1958). Letter. (3 *refs.*)

(1516) **On reducing aerodynamic heat transfer rates by magneto-hydrodynamic techniques.** R. C. Meyer. *J. Aero. Sci.*, **25** (9), 561–6, 572 (*Sept.*, 1958). Analyses the modifications of flow by means of a magnetic field, concludes that the primary mechanism which serves to reduce heat transfer is an alteration of the inviscid flow external to the boundary layer. From a cursory examination it does not seem practicable to reduce the aerodynamic heating load on flat plates by magnetic techniques unless the electrical conductivity of air is artificially enhanced. (8 *refs.*)

.3 *Rocket-Propelled Aircraft*

(1517) **Rocket.** P. B. Joubert de la Ferté, 190 pp., $6.00, *Philosophical Library, N.Y.* (1958), 18s., *Hutchinson, London* (1958). Book.

(1518) **X-15, Dyna-Soar will put man in space.** R. Sweeney. *Aviation Wk.*, **68** (24), 117–8, 122–3, 125–6 (16 *June*, 1958). Describes these projects, typical flight programmes, and problems they will investigate.

(1519) **X-15 rolls out; capability for Mach 7 is visualised.** I. Stone. *Aviation Wk.*, **69** (16), 26–9 (20 *Oct.*, 1958). General description of this rocket-powered research aircraft.

.4 *Test Facilities*

(1520) **New test tools needed for space age.** *Aviation Wk.*, **68** (24), 179–80, 183–5 (16 *June*, 1958). Super and hypersonic test facilities described. Various techniques are compared.

6—ASTRONAUTICS

.1 *General*

[*See also* abstract no. 1490]

(1521) **The age of space. Proceedings of a non-technical conference on missiles, rockets and space travel and their impact on our times.** 43 pp. *Southern Res. Inst., Birmingham, Ala., U.S.A.* (1957). Book.

(1522) **Space research and exploration.** ed. D. R. Bates and P. A. Moore, 224 pp., 25s. *Eyre and Spottiswoode, London* (1957). *McClelland and Stewart, Toronto* (1958). 287 pp., $4.00, *Sloane, N.Y.* (1958). Book.

(1523) **The space encyclopaedia.** ed. M. T. Bizony. 287 pp., 35s. *Artemis Press, London* (1957). Book.

(1524) **Realities of space travel.** ed. L. J. Carter, 431 pp., $7.50, *McGraw Hill, N.Y.* (1957), 35s., *Putnam, London* (1957). *McClelland and Stewart, Toronto* (1957). Book.

(1525) **Rockets, missiles and moons.** C. Coombs, 256 pp., *William Morrow, New York* (1957). Book.

(1526) **Rockets, missiles and space travel.** W. Ley. 528 pp., 50s., *Chapman and Hall, London* (1957). $6.75, *Viking, N.Y.* (1957). $7.50, *Macmillan, Toronto* (1957). Book, revised ed.

(1527) **Man among the stars.** W. D. Müller, ed. W. R. Young. 307 pp., $4.95, *Criterion Books, N.Y.* (1957). $5.25, *Nelson, Foster and Scott, Toronto* (1957). 18s., *Harrap, London* (1958). Book.

(1528) **The race for space.** ed., P. G. Neimark: *Camerarts Pub. Co., Chicago* (1957). Book. Collection of 15 articles.

(1529) **Soviet writings on Earth satellites and space travel.** $3.95, *Citadel Press, N.Y.* $4.75, *McLeod, Toronto* (1958). Book.

(1530) **Ten steps into space.** 170 pp., $4.00, *Franklin Institute, Philadelphia, U.S.A.* (1958). Book.

(1531) **Space flight.** C. C. Adams *et al.* 373 pp., $6.50, 50s. 6d., *McGraw Hill, N.Y., and London* (1958). Book.

(1532) **Vistas in astronautics.** ed. M. Alperin *et al.* 330 pp., $15.00, £5 5s., *Pergamon Press, N.Y. and London* (1958). Book. International Series of monographs on aeronautical sciences and space-flight, division 7, vol. 1. Reviewed *J.B.I.S.*, 1959–60, **17**, 111.

(1533) **Rockets, satellites and space travel.** J. Coggins and F. Pratt. 64 pp., $1.95, *Random House, N.Y.* (1958). Juvenile book, revised version of **Rockets, jets, guided missiles and spaceships.**

(1534). **Spacepower, what it means to you.** D. Cox and M. Stoiko. 262 pp., $4.50. *John C. Winston Co., Philadelphia and Toronto* (1958). Book.

(1535) **All about satellites and space-ships**. D. Dietz. 164 pp., $1.95. *Random House, N.Y.* $2.50, *Random House, Toronto* (1958). Juvenile book.

(1536) **What's going on in space?** D. C. Holmes. 256 pp., $3.95, *Funk and Wagnalls, N.Y.* (1958). Book.

(1537) **Rockets, missiles and satellites**. C. Knight. 61 pp., $1.95, *Grosset and Dunlap, N.Y.* (1958). Juvenile book.

(1538) **Flight into space**. J. N. Leonard. 306 pp., $0.95, *Modern Library, N.Y.* (1958). Book, paper-back edition, revised.

(1539) **Space travel**. W. Ley. 44 pp., $1.00, *Guild Press, N.Y.* (1958). Juvenile book.

(1540) **There's adventure in rockets**. J. May. 192 pp., $2.95, *Popular Mechanics, N.Y.* (1958). Juvenile book.

(1541) **Space book for young people**. H. E. Newell. 115 pp., $2.95, *McGraw Hill, N.Y.* (1958). Juvenile book.

(1542) **Guide to rockets, missiles and satellites**. H. E. Newell. 54 pp., $2.50, *McGraw Hill, N.Y.* $2.95, *McGraw Hill, Toronto* (1958). Juvenile book.

(1543) **Handbook of space flight**. W. A. Proell and N. J. Bowman. 458 pp., $8.00, *Perastadion Press, Chicago* (1958). Book, second edition.

(1544) **The scientific uses of space exploration**. F. Hoyle. *J. Inst. Metals*, **88**, 1–6 (1959–60). 49th May Lecture.

(1545) **Optimum pay-load ratio relation for multiple-stage rockets**. G. Leitmann. *Amer. J. Phys.*, **26** (1), 28–30 (*Jan.*, 1958). Reviews the principles of the multiple-stage rocket. Shows that the overall payload-ratio of a multiple-stage rocket is smallest when the payload-ratio of all stages are equal, but the minimum is not sharp.

(1546) **Business implications of future space flight systems**. W. H. Dorrance. *Aero. Engng. Rev.*, **17** (2), 20–3 (*Feb.*, 1958). An analysis of the military, scientific and commercial applications of spaceflight systems from the point of view of assessing their business implications for the airframe industry. (9 *refs.*)

(1547) **There'll be some changes made as U.S. readies for space age**. *Amer. Machinist*, **102**, 138–9 (24 *Feb.*, 1958).

(1548) **Space technology and the N.A.C.A.** H. L. Dryden. *Aero. Engng. Rev.*, **17** (3), 32–4, 44 (*March*, 1958). An assessment of the revision of outlook necessary with man's progress towards spaceflight.

(1549) **Introduction to the problems and possibilities of spaceflight**. *Weltraumfahrt*, **9**, 33–40 (*June*, 1958). (*In German.*) Text of speech by President Eisenhower.

(1550) **On space-ships man is not needed**. F. Fiorio. *Alata*, **14** (156), 21–3, 56 (*June*, 1958). (*In Italian.*)

(1551) **A.R.P.A. shapes military space research**. *Aviation Wk.*, **68** (24), 83–5 (16 *June*, 1958). Describes the Advanced Research Projects Agency and some of the projects in which it is interested.

(1552) **Boeing proposes solid-propellant space and re-entry test vehicle**. *Aviation Wk.*, **69** (22), 51–2 (1 *Dec.*, 1958).

(1553) **Industry faces stiff space age rivalry**. *Aviation Wk.*, **68** (24), 93–4 (16 *June*, 1958). The problems of American industry in turning from aircraft towards spacecraft. Need for greater investment in plant, and governmental fiscal policy are discussed.

(1554) **Navy moves to establish space mission**. *Aviation Wk.*, **68** (24), 89–90 (16 *June*, 1958). Satellite and space probe interests of the U.S. Navy.

(1555) **Soviet lead in space due to foresight**. *Aviation Wk.*, **68** (24), 285–8 (16 *June*, 1958). Describes Russian achievement in spaceflight, compares U.S. and Russian satellites.

(1556) **U.S.A.F. space effort based on research**. *Aviation Wk.*, **68** (24), 86–8 (16 *June*, 1958). Some of the U.S.A.F. space and upper atmosphere projects described with notes on the organization of military research.

(1557) **Europe's space research is on paper**. D. A. Anderton. *Aviation Wk.*, **68** (24), 289–90 (16 *June*, 1958). Discusses the over-riding effect of lack of finance on European space research.

(1558) **Research reveals new problems in space**. J. A. Fusca. *Aviation Wk.*, **68** (24), 76 (16 *June*, 1958). Draws attention to new knowledge of the Sun's atmosphere, magnetohydrodynamics and Earth's magnetic field.

(1559) **N.A.C.A. shifting to space agency role**. R. Hotz. *Aviation Wk.*, **68** (24), 79–82 (16 *June*, 1958). Describes the reorganization of the N.A.C.A. and its future increased interest in space exploration.

(1560) **The role of manned balloons in the exploration of space**. M. D. Ross and M. L. Lewis. *Aero-Space Engng.*, **17** (8), 45–52, 56 (*Aug.*, 1958). A review of earlier sealed-cabin balloon ascents, and a first-hand account of the *Strato-Lab. High* 2 balloon ascent of October, 1957, a 9-hr. flight up to 85,000 ft. (31 *refs.*)

(1561) **Moon refuelling for interplanetary vehicles**. K. R. Stehling. *Aviation Age*, **30** (2), 22–3 (*Aug.*, 1958). Considers the advantages of using the Moon as a propellent storage base for interplanetary exploration. Problems of propellent storage are discussed.

(1562) **Long-range rockets and satellites**. E. C. Cornford. *Engng.*, **186**, 282–7 (29 *Aug.*, 1958). Paper delivered to British Association covering performance, guidance and control.

(1563) **N.A.S.A. gets set for space research job**. R. M. Loebelson. *Space-Aeronautics*, **30** (4), 18–9, 192–4 (*Oct.*, 1958). Account of the organization and objectives of the National Aeronautics and Space Administration of the U.S.A.

(1564) **High spots of Amsterdam Congress**. K. R. Stehling. *Space-Aeronautics*, **30** (4), 184–90 (*Oct.*, 1958). Account of Ninth I.A.F. Congress proceedings, stresses papers on electric propulsion, radiation, magnetohydrodynamics.

(1565) **Ninth International Astronautical Congress**. G. V. E. Thompson. *Aircraft Engng.*, **30**, 342–4 (*Nov.*, 1958). Summaries of some of the more important papers given at the Congress held in Amsterdam, August, 1958.

(1566) **Space vehicle escape methods studied**. C. Lewis. *Aviation Wk.*, **69** (21), 49, 51 (24 *Nov.*, 1958). General discussion of the problems reported from a symposium on the physics and medicine of air and spaceflight.

(1567) **Space vehicles, satellites, and missiles**. *Elect. Engng. (N.Y.)*, **77**, 1077–95 (*Dec.*, 1958). A symposium on the control of space-vehicles, including the following papers and record of the discussion. **The motions of satellites**. I. M. Levitt. **Spaceflight guidance**. C. S. Draper. **Dynamic stabilization in large rocket vehicles**. R. E. Hanna. **Attitude control I**. J. S. Farrior. **Attitude control II**. R. E. Roberson. (6 *refs.*). **Attitude control III**. D. B. de Bra and E. V. Stearns. (4 *refs.*) **System design**. J. L. Bowers.

.2 *Artificial Satellites*

[*See also* abstracts nos. 1448, 1449, 1451, 1452, 1455–1459, 1461, 1473–1475, 1480, 1485, 1665, 1666, 1668–1674, 1676–1689, 1692, 1693, 1724, 1777, 1783, 1791, 1792, 1794, 1796–1803, 1805, 1806, 1808–1815, 1817–1819, 1821–1831, 1833, 1834, 1836, 1837, 1840, 1841, 1845, 1847, 1848, 1856, 1858, 1860, 1861, 1863–1865, 1867–1880, 1891].

(1568) **Satellite!** E. Bergaust and W. Beller. 287 pp., $3.95, *Doubleday, N.Y.* (1956). 239 pp., 17s. 6d., *Lutterworth Press, London* (1957). Book.

(1569) **Sputnik. What are its technical implications?** *Electron. Ind. and Tele-Tech.*, **16**, 70–1, 73, 149–50 (1957).

(1570) **Satellites and computers—and psychology**. E. C. Berkeley. *Computers and Automation*, **6**, 6–8, 14 (1957).

(1571) **Operation Vanguard: Earth satellite**. W. Buedeler. 128 pp., 16s., *Burke, London* (1957). $3.00, *Ambassador Books, Toronto* (1957).

(1572) **Satellites and spaceflight**. E. Burgess. 159 pp., 21s., *Chapman and Hall, London* (1957). $3.95, *Macmillan, N.Y.* (1958). Book.

(1573) **Vanguard: the story of the first man-made satellite**. M. Caidin. 288 pp, *E. P. Dutton and Co., New York* (1957). Book.

(1574) **The making of a Moon**. A. C. Clarke. 205 pp., $3.50, *Harper and Bros., New York* (1957). Book.

(1575) **On the observation of the arificial satellite**. A. A. Mikhailov. *Astronomicheskii Zhurnal*, **34**, 313 (1957). (*In Russian.*) Available in English, *Trans. No. R-2679, Special Libraries Association Translation Center, Crerar Library, Chicago.*

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(1577) **Earth satellites and the race for space superiority**. G. H. Stine. 190 pp., *Ace Books, New York* (1957).

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(1614) **Amateur astronomers. Some satellite observing statistics.** *Sky and Telescope*, **17**, 182 (*Feb.*, 1958).

(1615) **Plastics nose to guard U.S. satellite in flight.** *Plastics Techn.*, **4**, 142 (*Feb.*, 1958).

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(1617) **Explorer and what it means!** *Electron. Ind.*, **17**, 56–7, 126 (*March*, 1958).

(1618) **1958 Alpha; tribute and promise to science.** R. W. Porter. *Gen. Electric Rev.*, **61**, 7 (*March*, 1958).

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(1622) **Analytical chemistry and the satellite.** *Anal. Chem.*, **30** (4, Part I), 15A–17A, 20A, 22A, 24A, 26A (*April*, 1958).

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(1629) **Some results of the American satellites.** *Weltraumfahrt*, **9**, 45–7 (*June*, 1958). (*In German.*). *Explorers I* and *II.*

(1630) **Vanguard.** *Weltraumfahrt*, **9**, 41–4 (*June*, 1958). (*In German.*)

(1631) **Artificial satellites: A bibliography of recent literature. Part Two—1957–8.** M. Benton. *Jet Propulsion*, **28**, 399–401, 418 (*June*, 1958).

(1632) **Satellite "eyes" to view Earth weather conditions.** W. Strouse. *Missiles and Rockets*, **3** (7), 72–5 (*June*, 1958).

(1633) **Orbiting laboratory.** K. W. Gatland. *Engng.*, **185**, 722–3 (6 *June*, 1958). *Sputnik III.*

(1634) **Army gaining vital space assignments.** *Aviation Wk.*, **68** (24), 137, 139, 141, 143–4 (16 *June*, 1958). The successful participation of the U.S. Army Ballistic Missile Agency in the early satellite launchings.

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(1637) **Vanguard components to get wide use.** E. Clark. *Aviation Wk.*, **68** (24), 131, 133, 135–6 (16 *June*, 1958). Reviews achievements of the Vanguard satellite programme.

(1638) **Man-in-space timetable still debated.** I. Stone. *Aviation Wk.*, **68** (24), 97, 99, 101, 103 (16 *June*, 1958). Discusses proposals for manned satellites, that of the U.S.A.F. in particular, and the chances of launching one by the end of 1959.

(1639) **Camera shows Sputnik II length.** *Industr. Labs.*, **9**, 21 (*July*, 1958).

(1640) **Sputniks over Britain.** G. C. Sponsler. *Physics Today*, **11**, 16–21 (*July*, 1958).

(1641) **Booster propulsion for space vehicles.** R. S. Wentnik. *Aero-Space Engng.*, **17** (7), 40–5, 51 (*July*, 1958). An investigation of the requirements for a recoverable booster stage for man and cargo-carrying orbital ferry rocket craft, and analysis with reference to present practicability.

(1642) **Drag devices may aid satellite recovery.** R. L. Sweeney. *Aviation Wk.*, **69** (1), 49, 51–2 (7 *July*, 1958). Methods of decelerating satellite vehicles and the results of observations of the Vanguard satellite.

(1643) **Plan manned space lab. to orbit in three years.** *Industr. Labs.*, **9**, 33 (*Aug.*, 1958).

(1644) **Halfway to infinity—a primer on Earth satellites.** J. R. Hurley and J. J. Taborek. *Machine Design*, **30** (16), 22–5 (7 *Aug.*, 1958). Basic concepts.

(1645) **The "Explorers."** W. von Braun. *Engr.*, **206**, 372–5 (5 *Sept.*, 1958). Paper delivered to 9th Congress of the I.A.F. Description of launching vehicle, instrumentation and orbits of *Explorers I* and *III*.

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(1647) **Use of artificial satellites to explore the Earth's gravitational field: results from Sputnik 2 (1957β).** R. H. Merson and D. G. King-Hele. *Nature*, **182**, 640–1 (6 *Sept.*, 1958). (6 *refs.*)

(1648) **Satellite experience.** *Engng.*, **186**, 370–1 (19 *Sept.*, 1958). Review of 9th Congress of the International Astronautical Congress.

(1649) **Rotation of artificial Earth satellites.** R. N. Bracewell and O. K. Garriott. *Nature*, **182**, 760–2 (20 *Sept.*, 1958). (3 *refs.*)

(1650) **Departure and return in interplanetary flight.** K. J. Bossart. *Aero-Space Engng.*, **17** (10), 44–52 (*Oct.*, 1958). Orbits in the close vicinity of a planet studied from the standpoint of flight economy. It is assumed that high thrust acceleration from chemical propulsion is used. One special case, of the return to Earth, is briefly considered.

(1651) **A new method of tracking artificial Earth satellites.** A. P. Willmore. *Nature*, **182**, 1008–10 (11 *Oct.*, 1958). Letter.

(1652) **U.S.A.F. proposes satellite relay stations.** P. J. Klass. *Aviation Wk.*, **69** (16), 85–8 (20 *Oct.*, 1958). Report of papers presented at a Washington symposium on space communications.

(1653) **The rocket's dimensions.** R. d'E. Atkinson. *Proc. Roy. Soc.* [*A*], **248**, 80–1 (28 *Oct.*, 1958). Possible figures for *Sputnik I* based on orbital measurements and optical data are radius 63 cm., length 1890 cm.

(1654) **N.A.S.A. asks specific capsule approach.** *Aviation Wk.*, **69** (21), 28–31 (24 *Nov.*, 1958). The specification for a Man-in-Space capsule discussed in detail.

(1655) **Explorer data analysis may take years.** E. Clark. *Aviation Wk.*, **69** (22), 49 (1 *Dec.*, 1958). Discussion of the three successful Explorer satellites, reported from paper by G. Robillard.

(1656) **North American, G.E. make joint manned satellite bid.** E. Clark. *Aviation Wk.*, **69** (22), 32–4 (1 *Dec.*, 1958). Firm's proposals for a man-carrying space capsule.

.3 *Lunar and Planetary Probes*

[*See also* abstract no. 1724]

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(1658) **Moon trip; true adventure in space.** W. A. Nephew and M. Chester. 63 pp., $2.50, *Putnam, N.Y.* $3.00, *Longmans, Toronto* (1958). Juvenile book.

(1659) **Probes will explore cislunar space.** I. Stone. *Aviation Wk.*, **68** (24), 165, 167, 169–73 (16 *June*, 1958). The general problems of Moon-probes and details of particular projects.

(1660) **First U.S. lunar probe fails after promising launch.** E. Clark. *Aviation Wk.*, **69** (8), 20–3 (25 *Aug.*, 1958). Illustrated description of vehicle and its failure after launch.

(1661) **Lunar probe paths for approaching the Moon.** G. V. E. Thompson. *Engng.*, **186**, 294–5 (5 *Sept.*, 1958). (5 *refs.*)

(1662) **Moon vehicles for today or tomorrow.** K. R. Stehling. *Space-Aeronautics*, **30** (5), 22–3, 200–1 (*Nov.*, 1958). An outline of the types of vehicle required to carry payloads of 100 lb. to 10 tons to the vicinity of the Moon.

(1663) **Lunar probe second stage readied for Florida launching.** *Aviation Wk.*, **69** (21), 59 (24 *Nov.*, 1958). Pictures.

.4 *Spaceships*

(1664) **A new "speedometer" for space travel.** J. M. Dukert. *Space-Aeronautics*, **30** (5), 210–1 (*Nov.*, 1958). Proposal for display which gives space-crew information on height and velocity and the ratio of velocity to orbital velocity.

.6 *Orbits*

[*See also* abstracts nos. 1575, 1579, 1602, 1614, 1627, 1651, 1783 and 1805]

(1665) **On the motion of a satellite of an oblate planet.** B. Garfinkel. *Aberdeen Proving Ground, Ballistic Research Laboratories Rept.* 1018, 33 pp. (*July*, 1957).

(1666) **Perturbations of a close satellite by the equatorial ellipticity of the Earth.** J. A. O'Keefe. *Astr. J.*, **62**, 183–5 (*Aug.*, 1957).

(1667) **Transfer between vehicles in circular orbits.** B. H. Paiewonsky. *Wright Air Development Center, Dayton, Tech. Note S7–267*, 9 pp. (*Aug.*, 1957).

(1668) **Effect of geophysical factors upon the motion of an artificial satellite.** I. M. Yatsunskü. *Uspekikh Fizicheskikh Nauk*, **63** (1a), 59–71 (*Sept.*, 1957). (*In Russian.*) Available in English, *Trans. No. R–3054, Special Libraries Association Translation Center, Crerar Library, Chicago.*

(1669) **Determination of the lifetime of an artificial Earth satellite and investigation of the secular perturbations of its orbit.** D. E. Okhotsimskii, T. M. Eneev and G. P. Taratynova. *Uspekhi Fiz. Nauk*, **63** (1a), 33–50 (*Sept.*, 1957). (*In Russian.*) Available in English, *Trans. No. R–3053, Special Libraries Association, Translation Center, Crerar Library, Chicago.* [*See also* abs. no. 294, *J.B.I.S.*, **16**, 440 (*May-June*, 1958).

(1670) **The motion of an artificial Earth satellite in the eccentric gravitational field of the Earth when atmospheric resistance is taken into account.** G. P. Taratynova. *Uspekhi Fizicheskikh Nauk*, **63** (1a), 51–8 (*Sept.*, 1957). (*In Russian.*) Available in English, *Trans. No. R–3057, Special Libraries Association Translation Center, Crerar Library, Chicago.* [*See also* abs. no. 295, *J.I.B.S.*, **16**, 440 (*May–June*, 1958).]

(1671) **An application of Jacobi's integral to the motion of an Earth satellite.** J. A. O'Keefe. *Astr. J.*, **62**, 265–6 (*Oct.*, 1957).

(1672) **Orbit measurements of an artificial Earth satellite (Sputnik II) from photographs taken with a tracking ballistic telescope system.** D. Reuyl. *Aberdeen Proving Ground, Ballistic Research Laboratories Tech. Note* 1156 (*Nov.*, 1957).

(1673) **Celestial mechanisms of artificial satellites.** T. E. Sterne. *Sky and Telescope*, **17**, 66–8 (*Dec.*, 1957).

(1674) **Orbital data and preliminary analyses of satellites 1957 alpha and 1957 beta.** F. L. Whipple, L. G. Boyd, J. A. Hynek and G. F. Schilling. *Smithsonian Contributions to Astrophysics*, **2** (10), 189–347 (1958).

(1675) **Space navigation challenges designers.** P. J. Klass. *Aviation Wk.*, **68** (24), 217, 219–20, 225 (16 *June*, 1958). Discusses the need for very high accuracy in interplanetary navigation, and methods for determining navigational data.

(1676) **Motion of the nodal line of the second Russian Earth satellite (1957β) and flattening of the Earth.** E. Buchar. *Nature*, **182**, 198–9 (19 *July*, 1958). Letter. (2 *refs.*)

(1677) **Effect of transverse atmospheric drag on satellite orbits.** W. A. Wildhack. *Science*, **128**, 309–10 (8 *Aug.*, 1958). Letter. Approximate formula derived assuming a polar orbit and perigee at the equator. Effect shown to be of major importance during last few thousand miles of final orbit.

(1678) **The last minutes of satellite 1957β (Sputnik 2).** D. G. King-Hele and D. M. C. Walker. *Nature*, **182**, 426–7 (16 *Aug.*, 1958).

(1679) **Effect of solar flares on Earth satellite 1957β.** T. R. F. Nonweiler. *Nature*, **182**, 468–9 (16 *Aug.*, 1958). Letter.

(1680) **Sputnik I's last three days in orbit.** J. D. Kraus and E. E. Dreese. *Proc. Inst. Radio Engrs.*, **46**, 1580–7 (*Sept.*, 1958).

(1681) **Seasonal illumination of a circumpolar Earth satellite at its extreme-latitude orbit point.** W. N. Abbott. *Nature*, **182**, 651–2 (6 *Sept.*, 1958). Letter.

(1682) **The effect of the Earth's oblateness on the orbit of a near satellite.** D. G. King-Hele. *Proc. Roy. Soc* [A], **247**, 49–72 (9 *Sept.*, 1958). Equations of motion solved analytically by a perturbation method. Solution applies primarily to orbits of eccentricity of 0·05 or less. The accuracy of the solution for radial distance should then be about 0·001% and the error in angular travel about 0·001% per revolution. (15 *refs.*)

(1683) **Effect of air drag on the orbit of an Earth satellite.** *Nature*, **182** (20 *Sept.*, 1958). D. G. Parkyn, 787–8 (2 *refs.*). D. G. King-Hele and D. C. M. Leslie, 788. Two letters.

(1684) **An irregularity in the atmospheric drag effects on Sputniks 2 and 3 (satellites 1957β, 1958δ1, and 1958δ2).** D. G. King-Hele and D. M. C. Walker. *Nature*, **182**, 860–1 (27 *Sept.*, 1958). Letter. (1 *ref.*)

(1685) **Elliptic orbits in a frictional atmosphere.** D. G. Parkyn. *Amer. J. Phys.*, **26** (7), 436–40 (*Oct.*, 1958). A discussion of the effect of an atmosphere of variable density on the motion of a body travelling in an elliptic orbit. An atmospheric model is postulated and calculations of satellite lifetimes are compared with those observed for *Sputnik I.*

(1686) **The computation of orbit parameters from interferometer and Doppler data.** E. G. C. Burt. *Proc. Roy. Soc.* [A], **248**, 48–55 (28 *Oct.*, 1958). A digital computer programme has been prepared and results of calculations are presented. (1 *ref.*)

(1687) **Method for computations of satellite orbits.** L. Jacchia. *Proc. Roy. Soc.* [A], **248**, 43–4 (28 *Oct.*, 1958). Use of I.B.M. 704.

(1688) **Perturbations of the orbit of a satellite near to the Earth.** D. G. King-Hele. *Proc. Roy. Soc.* [A], **248**, 55–62 (28 *Oct.*, 1958). Considers Earth's oblateness and atmospheric drag which are treated separately. This is a first approximation but for more thorough analysis cross-couplings must be evaluated. Drag reduces the length of the major axis, the eccentricity and the period and the rate of change of all these quantities increases. Oblateness rotates plane of orbit and major axis but with no change of length. (3 *refs.*)

(1689) **The prediction service of H.M. Nautical Almanac Office.** D. H. Sadler. *Proc. Roy. Soc.* [A], **248**, 45–8 (28 *Oct.*, 1958). Forms and methods of prediction and precision required. Observations accurate to 1° and 1 sec. are useful for orbital determination but for geodetic work 0·001° and 0·001 sec. are desirable.

(1690) **An application of solar radiation to space navigation.** S. J. Press. *Aero-Space Engng.*, **17** (11), 51–4 (*Nov.*, 1958). In outer space travel conventional methods of navigating are not expected to be sufficiently accurate, the use of thermal detectors may solve the problem. (9 *refs.*)

(1691) **Progress of the Russian Earth satellite Sputnik 3 (1958δ).** D. G. King-Hele. *Nature*, **182**, 1409–11 (22 *Nov.*, 1958). (4 *refs.*)

(1692) **Change of inclination of a satellite orbit.** C. H. Bosanquet. *Nature*, **182**, 1533 (29 *Nov.*, 1958). Letter. (1 *ref.*)

(1693) **Irregularities of satellite drag and diurnal variations in density of the air.** G. V. Groves. *Nature*, **182**, 1533–4 (29 *Nov.*, 1958). Letter. (1 *ref.*)

(1694) **Some problems of space navigation.** R. E. Roberson. *Aero-Space Engng.*, **17** (12), 39–43, 54 (*Dec.*, 1958). The field of knowledge of space navigation reviewed. Seven problems are listed as being the chief lines along which research should be directed. (15 *refs.*)

7—PROPULSION

.1 *General*

[*See also* abstract no. 1564]

(1695) **Aircraft and missile propulsion.** M. J. Zucrow. Vol. 1, 538 pp., $11.50 or $9,50. *Wiley, N.Y.*, 92s, *Chapman and Hall, London.* Vol. 2, $13.00, *Wiley, N.Y.* (1958). Book. Vol. 1, Thermodynamics of fluid flow and application to propulsion engines. Reviewed *J.B.I.S.*, 1959–60, **17**, 112. Vol. 2, The gas turbine engine, turboprop, turbojet, ramjet and rocket.

(1696) **Relativistic treatment of rocket kinematics and propulsion.** P. F. von Handel and H. Knothe. *U.S.A.F. Missile Development Center, TR* 58–3, 83 pp. (*Jan.*, 1958). A mathematical investigation using the special theory of relativity. The effects of reception and expulsion of particles and radiations are examined in detail. The optimization of the final velocity of the vehicle is determined in terms of the energy available and the payload.

(1697) **Propulsion systems for space flight.** R. B. Dillaway. *Aero. Engng. Rev.*, **17** (4), 42–9, 52 (*April*, 1958). Typical designs for chemical, nuclear and ion rocket engine systems are described, and available information on radiation, particles, and gravitational attraction is reviewed in regard to their effects on propulsion systems.

(1698) **Advanced propulsion research speeded.** *Aviation Wk.*, **68** (24), 277, 279–80 (16 *June*, 1958). A nuclear rocket is now under development, research on ion and plasma propulsion, free radicals and other devices are described.

.2 *Ram-Jets and Air-Breathing Engines*

(1699) **Air-breathing power plants in the space era.** P. G. Kappus. *Aero-Space Engng.*, **17** (11), 62–5, 69 (*Nov.*, 1958). Trends in the development of gas turbine engines, their uses in improving transport aircraft and application as boost engines for rocket vehicles.

.3 *Chemical Rockets*

[*See also* abstracts nos. 1481, 1599 and 1641]

GENERAL

(1700) **Calculations for rocket motors.** H. G. Mebus. 120 pp. *C.F. Winter'sche Verlagsbuchhandlung, Germany* (1957). (*In German.*) Book.

(1701) **On the efficiency of rockets and the energy content of fuels.** P. Glansdorff, A. Jaumotte and J. Passelecq. *Fusées*, **2**, 205–12 (*July*, 1957). (*In French.*) (11 *refs.*)

(1702) **On the thermodynamics of expanding combustion gases.** E.-E. Büchner. 213 pp., 28.00 D.M., *Paul Herbig-Verlag, Germany* (1958). (*In German.*) Book. Special application to rocket motors.

(1703) **The thrust of a supersonic conical nozzle with non-isentropic flow.** P. N. Rowe. *Proc. Inst. Mech. Engrs.*, **172**, 877–88 (1958). (10 *refs.*)

(1704) **On the influence of the form of the combustion chamber of rockets.** L. Poggi. *Aerotecnica*, **38** (2), 109–10 (*April*, 1958). (*In Italian.*) From simple considerations determines the influence, for a given thrust, of the rate of flow and the area of section where the combustion front is supposed to occur on combustion pressure and hence on mass. Concludes that the above section should have the same area as the throat.

(1705) **Exhaust nozzle contour for optimum thrust.** G. V. R. Rao. *Jet Propulsion*, **28**, 377–82 (*June*, 1958). (6 *refs.*)

(1706) **Television viewing of rocket engine tests.** J. P. Mitchell. *Soc. Mot. Pict. Televis. Engrs. J.*, **67**, 473–4 (*July*, 1958).

(1707) **Rocket-engine manufacture requires machining ingenuity.** C. O. Herb and W. E. Moller. *Machinery*, **65**, 121–6 (*Sept.*, 1958).

(1708) **Chemical rocket engines—principles and applications.** R. R. Bradley and J. G. Donovan. *Sperry Engng. Rev.*, **10**, 2 (*Sept.–Oct.*, 1957).

(1709) **Standby rocket engines for civil aircraft.** G. E. Rice. *Inst. Aero. Sci. Prepr.* 760, 19 pp. (*Oct.*, 1957).

.32 LIQUID-PROPELLENT ROCKETS

(1710) **Screamer details.** *Aeroplane*, **91**, 114 (27 *July*, 1956).

(1711) **Britain's first variable-thrust rocket.** *Aeroplane*, **91**, 255–60 (24 *Aug.*, 1956). A description of the Armstrong-Siddeley Snarler.

(1712) **The 8000-lb. s.t. Armstrong-Siddeley Screamer A.S.Sc. 1-2.** *Aeroplane*, **91**, 370–1 (7 *Sept.*, 1956). Annotated diagram of this engine.

(1713) **The problems of rocket engine development.** *Aeroplane*, **91**, 586 (19 *Oct.*, 1956). Report of a paper by S. Allen.

(1714) **Liquid-propellent rocket motors.** G. B. Sinyarev and M. V. Dobrovolskii. *Moscow* (1957). Book, 2nd edition.

(1715) **Theoretical study of decomposable liners for the protection of the walls of combustion chambers.** H. Gelly. *Fusées*, **2**, 219–28 (*July*, 1957). (*In French.*) (13 *refs.*)

(1716) **Effect of fluid-system parameters on starting flow in a liquid rocket.** R. P. Krabs. *N.A.C.A. Tech. Note* 4034, 38 pp. (*Sept.*, 1957).

(1717) **Experimental verification of nozzle admittance theory in a simulated rocket chamber.** S. Lambiris. *Princeton Univ., Dept. Aero. Engng. Rept.* 401, 48 pp. (*Sept.*, 1957).

(1718) **The "Spectre" rocket motor.** *Weltraumfahrt*, **9**, 48–50 (*June*, 1958). (*In German.*)

(1719) **De Havilland designs dual Spectre rocket.** *Aviation Wk.*, **69** (8), 25 (25 *Aug.*, 1958). News release of unit compound from Spectre 4 and Spectre 5.

(1720) **Bell reports fluorine engine; news sets off stock flurry.** *Aviation Wk.*, **69** (9), 23 (1 *Sept.*, 1958). Report of rocket engine tests.

(1721) **Liquid rockets best for low cost drone propulsion.** D. W. Childs. *Space-Aeronautics*, **30** (4), 48–54, 56–7 (*Oct.*, 1958). Of power units available for low-cost expendable target aircraft the bi-propellent rocket has advantages in flexibility, high performance, and cost. Propellent combinations and engine design are described.

(1722) **Reliability achievement and demonstration in a development program.** H. R. Lawrence and W. H. Amster. *Aero-Space Engng.*, **17** (10), 65–9 (*Oct.*, 1958). A programme is outlined for improvement and demonstration of the reliability of liquid rocket propulsion systems and similar equipment using development test data. (1 *ref.*)

(1723) **Flexibility helps build I.R.B.M. engines.** C. Lewis. *Aviation Wk.*, **69** (14), 60–1, 63, 65, 67, 69 (6 *Oct.*, 1958). Description and illustrations of production of Thor missile engines by Rocketdyne.

(1724) **Rocket propulsion requirements for satellites and Moon missions.** J. L. Sloop. *Aero-Space Engng.*, **17** (11), 36–44, 50 (*Nov.*, 1958). The velocity requirements for several missions are given. Describes alternative possibilities for propulsion in space, discusses high energy chemical rockets in more detail. Concludes with a summary of the work which must precede manned space flight. (10 *refs.*)

(1725) **Navy expands role for liquid propellants.** M. Yaffee. *Aviation Wk.*, **69** (21), 62, 67, 69 (24 *Nov.*, 1958). Liquid-propellent rocket advantages made available by prepackaging for storage in fuelled condition.

.33 PROPELLENTS

[*See also* abstracts nos. 1466, 1471, 1472, 1701, 1714 and 1715]

(1726) **Metal powders in missile and rocket fuels.** L. R. Frazier. *Proceedings 14th Annual Meeting Metal Powder Association*, 65–70 (1958). Fuel requirements, metal powder properties affecting flammability. Powders which can be used include B, Al, Mg, Zr; Zr–Ni, Ti, Si, ZrH_2 have been employed for related applications.

(1727) **A comparison of liquid oxygen and nitric acid as oxidants for rocket motors.** E.-E. Büchner. *Deutschen Arbeitsgemeinschaft für Raketentechnik Report*, 7.50 D.M. (*Feb.*, 1958). (*In German.*)

(1728) **Liquid propellents for rocket engines.** E. Macioce. *Aerotecnica*, **38** (1), 44–7 (*Feb.*, 1958). (*In Italian.*) The requirements of liquid propellents for rocket engines from various points of view are briefly considered. Information about future developments of chemical propellents is given.

(1729) **Boron-containing rocket propellents.** *Engng.*, **185**, 264 (28 *Feb.*, 1958).

(1730) **Market managers get ready for new sales outlets as metallic fuels vecome vital.** *Steel*, **142**, 95 (14 *April*, 1958).

(1731) **For rockets, tried tactics win solid fuel.** C. H. Chilton. *Chem. Engng.*, **65** (8), 126–29 (21 *April*, 1958). Process flowsheet for production of solid propellent for M–15 JATO rockets (16-sec., 1000-lb. wt. thrust); developed by Phillips Petroleum Co., now run by Astrodyne, Inc., at MacGregor, Texas. Co-polymer rubber, carbon black, NH_4NO_3, catalyst, plasticizer and curatives are compounded by techniques similar to those used in rubber processing.

(1732) **Some properties of a simplified model of solid propellant burning.** L. Green. *Jet Propulsion*, **28**, 386–92 (*June*, 1958). (9 *refs.*)

(1733) **Advances made in conventional fuels.** M. Yaffee. *Aviation Wk.*, **68** (24), 267–8, 271–2 (16 *June*, 1958). A review of research objectives in solid and liquid propellents.

(1734) **Ignition delays of perchlorosulfonitric oxidiser with different fuels.** H. Moutet. *Rech. Aéronaut.*, **66**, 23–33 (*Sept.*, 1958). (*In French.*) A method of measuring ignition delays in the laboratory is described. Means for decreasing these delays by improvement of oxidant and fuel are studied. The results are presented in abbreviated form and it is shown that the addition of perchloric acid to nitric acid gives very short delays at atmospheric and lower pressures. (5 *refs.*)

(1735) **Tetranitromethane as a rocket oxidant.** R. M. Corelli. *Aerotecnica*, **38** (6), 315–22 (*Dec.*, 1958). (*In Italian.*) This is potentially a good oxidant but the literature contains few references. This paper presents theoretical and experimental results on its properties, preparation, stability, and use as an oxidant. (30 *refs.*)

.4 *Nuclear Rockets, Working Fluid*

(1736) **Nuclear rocket propulsion.** R. V. Bussard and R. D. De Lauer. 370 pp., $10.00, 77s. 6d., *McGraw-Hill, N.Y. and London* (1958). Book.

.6 *Miscellaneous*

(1737) **Controlled fusion studies open space engine field.** J. S. Butz. *Aviation Wk.*, **68** (20), 50–1, 53, 55, 57 (19 *May*, 1958). A résumé of proposals for nuclear-fusion-powered plasma rockets, and discussion of the possibility of magnetohydrodynamic braking for space-vehicle re-entry.

(1738) **Hydromagnetic shocks used in nuclear fusion engine.** C. F. Johnson. *Aviation Age*, **30** (2), 30–6 (*Aug.*, 1958). A proposal for an engine for reaction propulsion using shock waves generated by a type of pulse-jet and concentrated by magnetic field to produce nuclear fusion. (15 *refs.*)

(1739) **Free radicals for high energy fuels.** D. E. Carr, H. M. Fox and E. D. Guth. *Space-Aeronautics*, **30** (4), 22–3, 191 (*Oct.*, 1958). The unsolved problems of production and storage of free radicals in usable form, and the benefits they could offer for propulsion.

8—MISSILES

.1 *General*

[*See also* abstracts nos. 1521, 1526, 1542, 1545 and 1562]

(1740) **Directory of government missile agencies**. $15.00. *Federal Procurement Publications, N.Y.* Book.

(1741) **Directory of guided missiles**. $15.00. *Federal Procurement Publications, N.Y.* Book.

(1742) **Directory of missile manufacturers**. $15.00. *Federal Procurement Publications, N.Y.* Book.

(1743) **Guided weapons**. E. Burgess. *Chapman and Hall, London* (1957). Book.

(1744) **History of German guided missiles development**. ed. T. Benecke and A. W. Quick. 420 pp., D.M. 32.00. *E. Appelhaus, Brunswick, Germany* (1957). Book. Papers delivered at AGARD Meeting, Munich, April, 1956.

(1745) **Development of the guided missile**. K. W. Gatland. $6.00. *Philosophical Library, N.Y.* (1957). Book, second edition.

(1746) **Guided missiles; operations, design and theory**. United States Dept. of the Air Force. 575 pp., $8.00, *McGraw-Hill, N.Y.* (1958). Book.

(1747) **Rocket building for students**. $2.00. *Rocket Research Institute, Inc., Sacramento, Calif., U.S.A.* (1958). Book.

(1748) **Missile engineering handbook**. C. W. Besserer. 600 pp., $14.50, £5 9s., *Van Nostrand, N.Y. and London* (1958). Book. Vol. 4 in series, Principles of Guided Missile Design.

(1749) **What makes guided missiles tick**. B. Kemp. 95 pp., $1.50. *American Electronics, N.Y.* (1958). Book.

(1750) **Supervision urged for amateur rocketeers**. *Safety Maintenance*, **115**, 48 (*March*, 1958).

(1751) **Where are American missiles?** G. Apostolo. *Alata*, **14** (156), 25–30 (*June*, 1958). (*In Italian.*)

(1752) **Cameras: top testing tool for missiles**. P. Fossen. *Missiles and Rockets*, **3** (7), 134–6, 139 (*June*, 1958).

(1753) **Recent advances in rocket reliability concepts**. M. Lipow. *Jet Propulsion*, **28**, 373–7 (*June*, 1958). (22 *refs.*)

(1754) **Reds build interim missile/sub. fleet**. F. G. McGuire. *Missiles and Rockets*, **3** (7), 64 (*June*, 1958).

(1755) **FBM submarine: ultimate weapon?** W. O. Miller. *Missiles and Rockets*, **3** (7), 125–6, 129, 131–2 (*June*, 1958).

(1756) **Model missiles mean mayhem**. J. V. Neeson. *Safety Maintenance*, **115**, 11–2+ (*June*, 1958).

(1757) **Automatic calibrator speeds missiles**. D. E. Perry. *Missiles and Rockets*, **3** (7), 144, 147–8, 151 (*June*, 1958).

(1758) **Cameras need stable mounting**. R. G. Sanders. *Missiles and Rockets*, **3** (7), 114, 117–8, 120 (*June*, 1958).

(1759) **Vital role set for new missile range**. R. Hawkes. *Aviation Wk.*, **68** (24), 197, 199–200, 205–6, 209 (16 *June*, 1958). Describes the new Pacific Missile Range.

(1760) **Overdesigning lowers U.S. missile reliability, Dr. von Karman says**. *Aviation Wk.*, **69** (9), 51 (1 *Sept.*, 1958).

(1761) **Limit design for economical missile structures**. L. A. Riedinger. *Space-Aeronautics*, **30** (4), 32–9 (*Oct.*, 1958). Indicates that for structures subject to aerodynamic or other heating, special account must be taken of thermally induced stresses. Examples with numerical solution are given.

(1762) **American missiles**. J. Klopp. *Docaéro*, **53**, 3–30 (*Nov.*, 1958). (*In French.*) A comprehensive survey of work on missiles in the United States. The organization and financing of their programme and the division of responsibility between different organizations are described. A general review of American missiles is included with data presented in tabular form. Concludes with details of the cost of missile development in time and dollars, the cost of missiles in production and the cost of launching sites.

(1763) **Missile lessons have application to space aeroelasticity problems**. *Aviation Wk.*, **69** (21), 53, 55, 57 (24 *Nov.*, 1958). Discusses excitation of vibration in missile panels and methods of flutter research.

.2 *Short-Range*

(1764) **Launchers challenge structural engineers**. *Missiles and Rockets*, **3** (7), 96–7 (*June*, 1958).

(1765) **Australian Malkara missile nears test**. *Aviation Wk.*, **69** (8), 47 (25 *Aug.*, 1958).

(1766) **Canadair to produce Sparrow II missile**. *Aviation Wk.*, **69** (8), 47 (25 *Aug.*, 1958).

(1767) **Douglas tailors plant for Nike-Hercules**. M. Yaffee. *Aviation Wk.*, **69** (22), 60–1, 63 (1 *Dec.*, 1958). Pictures and description of a production line for this missile.

.3 *Ballistic*

[*See also* abstract no. 1468]

(1768) **United States Air Force report on the ballistic missile; its technology, logistics and strategy**. ed. K. F. Gantz. 338 pp., $4.00, *Doubleday, N.Y.* $4.50, *Doubleday, Toronto* (1958). Book.

(1769) **From the ground up**. *Engng.*, **185**, 298–9 (7 *March*, 1958). Photos of Atlas launching.

(1770) **Atlas calls for new shock techniques**. *Missiles and Rockets*, **3** (7), 140, 143 (*June*, 1958).

(1771) **Air Force won't support Project Adam**. N. L. Baker. *Missiles and Rockets*, **3** (7), 40–1 (*June*, 1958).

(1772) **Titan handling system designed for speed**. E. J. Bultsan. *Aviation Wk.*, **69** (14), 99, 101 (6 *Oct.*, 1958). Description of equipment for handling this I.C.B.M. between its transport and launcher.

.4 *Upper Atmosphere Research*

[*See also* abstract no. 1459]

(1773) **Rockets as research vehicles**. P. H. Wyckoff. *Shell Aviation News* (233), 2–4 (*Nov.*, 1957).

(1774) **Experimental results of the U.S. rocket programme for the International Geophysical Year to 1 July, 1958**. J. Hanessian and I. Guttmacher. *National Research Council, U.S.A. I.G.Y. Rocket Report Serial No.* 1, 236 pp., $1.00 (1958).

(1775) **High altitude rockets**. *Electronic Engng.*, **30**, 30 (*Jan.*, 1958).

(1776) **Navy unveils low cost sounding rocket**. C. Lewis. *Aviation Wk.*, **69** (18), 49–51, 53 (3 *Nov.*, 1958). The genesis and uses of ARCAS, which uses solid propellent to reach 200,000 ft. altitude with a 12-lb. payload.

.5 *Trajectories*

(1777) **Equations of motion of a missile and a satellite for an oblate-spheroidal rotating Earth**. B. E. Kalensher. *Calif. Inst. Tech., Jet Prop. Lab. Memo.* 20–142, 36 pp. (12 *April*, 1957).

(1778) **The range of a guided missile and its dependence on certain arbitrary parameters**. H.-R. Voellmy. *Fusées*, **2**, 213–8 (*July*, 1957). (*In French.*)

(1779) **Generalised variational approach to the optimum thrust programming for the vertical flight of a rocket. II. Application of Green's theorem to the development of sufficiency proofs for particular classes of solutions**. A. Miele and C. R. Cavoti. *Purdue Univ. School Aero. Engng. Rept.* A–57–2 (A.F.O.S.R. TN 57–652) (*Aug.*, 1957).

(1780) **Exterior ballistics of rockets**. L. Davis *et al.* 457 pp., $8.50, *Princeton, N.J., U.S.A.* 64s., *Van Nostrand, London* (1958). $8.50, *Van Nostrand, N.Y.* (1958). Book.

(1781) **Apparent motion of a luminous target during subgravity trajectories**. G. J. D. Schock. *U.S.A.F. Aeromed. Field Lab., U.S.A.F. Missile Development Center TN* 58–3 (1958).

(1782) **Prediction of ballistic missile trajectories from radar observations**. I. I. Shapiro. 216 pp., $7.00, 54s. 6d., *McGraw-Hill, N.Y. and London* (1958). Book.

(1783) **Directory of ultra-long lenses for missile or Sputnik tracking**. *Industr. Photog.*, **7**, 64–5, 80 (*Feb.*, 1958).

(1784) **General formulation of powered flight trajectory optimization problems**. B. T. Fried. *J. Appl. Phys.*, **29**, 1203–9 (*Aug.*,

1958). Using a point particle model it is shown that steering and burning programmes are determined always by the same differential equations, different optimization problems corresponding simply to different boundary conditions. Extensions to variable mass, thrust and burning times is included. (6 *refs.*)

(1785) **Optimum burning time of high-altitude rockets.** L. E. Giorgieri. *Aerotecnica*, **38** (4), 195–209 (*Aug.*, 1958). (*In Italian.*) Presents a method for finding the optimum burning time for high-altitude rockets. Atmospheric drag is omitted but structural stressing is taken into account, hence the results will be poor when applied to small single-stage vehicles, but good results are given for large multi-stage vehicles. Gives the acceleration for which at-launch vehicle mass is a minimum, and presents results in graphical form for one-, two- and three-stage rockets. (8 *refs.*)

.6 *Guidance and Control*

[*See also* abstract no. 1567]

(1786) **Target simulator tests beam-rider missiles.** G. E. Hendrix. *Electronics*, **31** (5), 32–5 (31 *Jan.*, 1958).

(1787) **Intelligence sources for guidance.** A. S. Locke. *Aero. Engng. Rev.*, **17** (3), 45–9 (*March*, 1958). A discussion of the primary intelligence required in the case of stationary and moving targets, and in the latter category the problems for aerodynamic and ballistic missiles.

(1788) **Infra-red: new use for an old technique.** R. S. Estey. *Missiles and Rockets*, **3** (7), 107, 109–10, 112 (*June*, 1958).

(1789) **Guidance and control problems in the Air Force ballistic missile program. II.** J. C. Fletcher. *Aero-Space Engng.*, **17**(6), 65–8, 71 (*June*, 1958). Discusses the essential components of an inertial guidance system and their errors. By careful choice an orientation of the platform can be found which minimises the effect of accelerations on the target miss distance.

(1790) **Inertial guidance system uses digital integrator.** H. J. Weber. *Space-Aeronautics*, **30** (5), 134–8, 141–3 (*Nov.*, 1958). Describes the circuits and operation of a high-accuracy integrator used to compute distance from velocity measurement in an inertially guided missile.

9—RADIO AND ELECTRONICS: COMMUNICATIONS

[*See also* abstracts nos. 1496, 1587, 1597 and 1652]

(1791) **Commutation and nondestructive read-out of magnetic memory cores in Earth satellites.** R. L. Van Allen and C. B. House. 1957 *National Telemetering Conference Report.*

(1792) **A new satellite tracking antenna.** C. J. Slettin, F. S. Holt *et al. Inst. Radio Engrs.* (*N.Y.*) 1957 *I.R.E. Wescon Convention Record, Pt. I*, 244–61 (1957).

(1793) **Opticians aid electronics.** *Electronic Equipment*, **5**, 40–1 (*July*, 1957). Telescopic photographic recorder for missiles in flight and miniaturized components for weather-forecasting satellite.

(1794) **Tracking the man-made satellite.** M. Gunther. *Radio Televis. News*, **58**, 31–3 (*July*, 1957).

(1795) **The absorption of radio waves in space.** A. E. Lilley. *Scientific American*, **197** (1), 48–55 (*July*, 1957).

(1796) **Earth satellite instrumentation.** W. Matthews. *Elect. Engng.* (*N.Y.*), **76**, 562–7 (*July*, 1957).

(1797) **Telemetered data checks Vanguard flight.** F. W. Phalen. *Electron. Ind. and Tele-Tech.*, **16**, 40–1 (*July*, 1957).

(1798) **Observation of signals from artificial Earth satellites.** O. Rzhiga, A. Shakhovskoi and V. Dubrovin. *Radio*, (7), 17–25 (*July*, 1957). (*In Russian.*)

(1799) **A magnetometer for the satellite.** A. L. Bloom and L. E. Johnson. *Electron. Ind. and Tele-Tech.*, **16**, 76–8, 148, 150, 152, 154, 156, 158 (*Aug.*, 1957).

(1800) **Effects of satellite spin on ground-received signal.** J. T. Bolljahn. *Stanford Res. Inst., Applied Research Center Tech. Rept.* 6, 22 pp. (*Aug.*, 1957).

(1801) **Observation of signals from artificial Earth satellites.** O. Rzhiga, A. Shakhovskoi and V. Dubrovin. *Radio*, (8), 17–20 (*Aug.*, 1957). (*In Russian.*)

(1802) **Mark II Minitrack base-line components. Constructional details of antenna system for satellite tracking.** R. L. Easton. *QST*, **41**, 37–41 (*Sept.*, 1957).

(1803) **Radio observations of the Russian Earth satellite.** R. R. Brown, P. E. Green, B. Howland, R. M. Lerner, R. Manasse and G. Pettengill. *Inst. Radio Engrs. Proc.*, **45**, 1552–3 (*Nov.*, 1957).

(1804) **Miniaturizing magnetometers.** M. E. Packard. *Military Electronics*, **3**, 22–4 (*Nov.*, 1957).

(1805) **Radio and radar tracking of the Russian Earth satellite.** A. M. Peterson. *Inst. Radio Engrs. Proc.*, **45**, 1553–5 (*Nov.*, 1957).

(1806) **Brief report on hams and Sputnik I.** *QST*, **41**, 10–12 (*Dec.*, 1957).

(1807) **Power engineering takes to space.** *Power Engng.*, **61**, 67–9 (*Dec.*, 1957).

(1808) **Satellite monitoring.** *QST*, **41**, 13 (*Dec.*, 1957).

(1809) **Satellite 40 mc converter Sensitivity and stability in a design for use with amateur-band receivers.** G. Grammer. *QST*, **41**, 25–8 (*Dec.*, 1957).

(1810) **What to do about satellites.** G. Grammer. *QST*, **41**, 14–15, 174 (*Dec.*, 1957).

(1811) **Microlock. A tracking receiver for satellite communications.** H. L. Richter. *QST*, **41**, 20–4 (*Dec.* 1957).

(1812) **Earth satellite telemetry coding system.** R. W. Rochelle. *Elect. Engng.* (*N.Y.*), **76**, 1062–5 (*Dec.*, 1957) (*bibl.*).

(1813) **Antennas for satellite monitoring on 108 mc.** E. P. Tilton. *QST*, **41**, 18–9 (*Dec.*, 1957).

(1814) **Radiation observations with satellite 1958 Epsilon.** J. A. Van Allen, C. E. McIlwan and G. H. Ludwig. *Dept. Physics, State Univ. Iowa, SUI*-58–10 (1958).

(1815) **Vanguard 108; two-tube 108 mc converter.** R. Graham. *Radio-Electronics*, **29**, 101–3 (*Jan.*, 1958) (*bibl.*).

(1816) **Scientific telemetry for USNC-IGY.** W. Matthews and G. H. Ludwg. *QST*, **42**, 41–5, 160, 162, 164 (*Jan.*, 1958).

(1817) **Magnetic core event counter for Earth satellite memory.** D. H. Schaefer. *Elect. Engng.* (*N.Y.*), **77**, 52–6 (*Jan.*, 1958). (3 *refs.*)

(1818) **Transistorised memory monitors Earth satellite.** C. S. Warren, W. G. Rumble and W. A. Helbig. *Electronics*, **31** (3), 66–70 (17 *Jan.*, 1958).

(1819) **Batteries for Sputniks.** *Metal Progr.*, **73**, 112, 114 (*Feb.*, 1958).

(1820) **Diode counter calibrates missile testing camera.** S. E. Horsey. *Electronics*, **31** (7), 93–9 (14 *Feb.*, 1958).

(1821) **Cyclops cores simplify Earth-satellite circuits.** W. Matthews, R. W. Rochelle, C. B. House, R. L. Van Allen, D. H. Schaefer and J. C. Schaffert. *Electronics*, **31** (9), 56–63 (28 *Feb.*, 1958).

(1822) **Bell Telephone Laboratories—Western Electric Co. diffused transistors, voice of Explorer satellite.** *Bell Labs. Record*, **36**, 115 (*March*, 1958).

(1823) **Meteor ping from Sputnik II.** C. R. Graf. *QST*, **42**, 47 (*March*, 1958).

(1824) **Opportunity for amateur participation in I.G.Y. satellite programme.** G. Grammer. *QST*, **42**, 32 (*March*, 1958).

(1825) **Radio observations on the Russian satellites; panel discussion.** *Proc. Instn. Elect. Engrs.* [B], **105**, 81–115 (*March*, 1958).

(1826) **Detection of Sputniks I and II by continuous wave reflection.** J. D. Kraus. *Inst. Radio Engrs. Proc.*, **46**, 611–2 (*March*, 1958).

(1827) **Last days of Sputnik I.** J. D. Kraus. *Inst. Radio Engrs. Proc.*, **46**, 612–4 (*March*, 1958).

(1828) **Some signal characteristics of Sputnik I.** J. D. Kraus and J. S. Albus. *Inst. Radio Engrs. Proc.*, **46**, 610–1 (*March*, 1958).

(1829) **Telemetering from Explorer.** W. Matthews. *Electron. Ind.*, **17**, 58–9, 124 (*March*, 1958).

(1830) **Unusual propagation at 40 mc from the U.S.S.R. satellite.** H. W. Wells. *Inst. Radio Engrs. Proc.*, **46**, 610 (*March*, 1958).

(1831) **Getting satellite signals back to earth.** A. E. Dent. *New Scientist*, **3** (70), 16–8 (20 *March*, 1958). The problems of a satellite-to-Earth radio link, choice of frequency, transmitter power and aerial arrays.

(1832) **Loaded-lens antenna tracks missiles.** L. S. Miller. *Electronics*, **31** (13), 44–6 (28 *March*, 1958).

(1833) **Minitrack station of the Sohio Moonbeam group.** *QST*, **42**, 48–9 (*April*, 1958).

(1834) **Satellite Doppler measurements.** M. Bernstein *et al.* *Inst. Radio Engrs. Proc.*, **46**, 782–3 (*April*, 1958).

(1835) **World-wide I.G.Y. data collection; teletype equipment.** H. D. Dickstein. *Electron. Ind.*, **17**, 144–7 (*April*, 1958).

(1836) **Sideline sightings.** C. Kunze. *QST*, **42**, 46 (*April*, 1958).

(1837) **Reduced-size satellite transmitters coming.** R. M. Nolan. *Missiles and Rockets*, **3** (4), 152–3 (*April*, 1958).

(1838) **Power for space.** B. G. A. Skrotzki. *Power*, **102**, 84–6, 186, 188, 190 (*April*, 1958).

(1839) **Ferrite radiators shrink missile antenna systems.** H. C. Hanks. *Electronics*, **31** (17), 49–51 (25 *April*, 1958) (2 *refs.*)

(1840) **Explorer III features improved signalling.** *Civil Engineering*, **28**, 386 (*May*, 1958).

(1841) **Microlock: club activity of the San Gabriel valley radio club.** *QST*, **42**, 70–1 (*May*, 1958).

(1842) **Thermistor speeds pre-launch check.** R. L. Biesele. *Missiles and Rockets*, **3** (6), 213, 215–7 (*May*, 1958).

(1843) **Interplanetary communication and navigation.** P. A. Castruccio. *Westinghouse Engr.*, **18**, 88–92 (*May*, 1958).

(1844) **New computer system speeds missile work.** P. Fossen. *Missiles and Rockets*, **3** (6), 207, 210 (*May*, 1958).

(1845) **High resolution TV tube for satellite.** N. F. Fyler. *Electron Ind.*, **17**, 5 (*May*, 1958).

(1846) **In-line relay cuts launching delays.** R. M. Nolan. *Missiles and Rockets*, **3** (6), 219, 221 (*May*, 1958).

(1847) **Doppler equation for Earth satellite measurements.** A. Schwartzmann and P. D. Stahl. *Inst. Radio Engrs. Proc.*, **46**, 915–6 (*May*, 1958).

(1848) **Electromagnetic analogs for the gravitational fields in the vicinity of a satellite.** W. D. White. *Inst. Radio Engrs. Proc.*, **46**, 920–2 (*May*, 1958).

(1849) **Scanning the skies.** N. L. Baker. *Missiles and Rockets*, **3** (7), 76–9 (*June*, 1958). Radar tracking, telemetry tracking, optical tracking.

(1850) **Antennas are getting bigger and sandwich construction keeps them in shape.** H. Holland. *Missiles and Rockets*, **3** (7), 89, 91, 95 (*June*, 1958).

(1851) **Telemetry: key to missile operation.** R. M. Nolan. *Missiles and Rockets*, **3** (7), 67–71 (*June*, 1958).

(1852) **Power sources for space explored.** J. A. Fusca. *Aviation Wk.*, **68** (24), 235, 237, 239, 241 (16 *June*, 1958). Physically possible sources of power and comparisons of their practicability.

(1853) **Space communications techniques ready.** J. A. Fusca. *Aviation Wk.*, **68** (24), 229–30, 233 (16 *June*, 1958). Communication with Mars and Venus is already technically possible, the rest of the solar system could be reached with methods already being explored.

(1854) **Space to spark avionics revolution.** P. J. Klass. *Aviation Wk.*, **68** (24), 243, 245–6, 249, 253, 256, 258, 263 (16 *June*, 1958). The requirements of spaceflight for smaller, lighter and more reliable electronic equipment has led to the development of the micro-miniature components and assemblies described.

(1855) **Small power plants for use in space.** L. Rosenblum. *Aero-Space Engng.*, **17** (7), 30–33, 51 (*July*, 1958). Considers power plants using three energy sources; chemical, solar and nuclear; capable of an electric power output in the range of 100 to 1000 W. (17 *refs.*)

(1856) **Telemeter transmitter for Vanguard rocket.** N. Raskhodoff. *Electronics*, **31** (27), 46–7 (4 *July*, 1958). Used for telemetering engine performance data. Voltage variations representing performance are picked up with a commutator and converted to pulse width modulated signals by a keyer. Duration of pulse width shifts frequency of crystal-controlled oscillator producing p.w.m./f.m. signal which is frequency multiplied, amplified and fed to antenna. Power supply is transistorised.

(1857) **New batteries for the space age.** D. Linden and A. F. Daniel. *Electronics*, **31** (29), 59–65 (18 *July*, 1958). Reviews characteristics and assesses uses of Leclanché and mercury dry cells, lead/acid, nickel/cadmium, zinc/silver oxide, thermal, chlorine-depolarized and ammonia-vapour-activated cells.

(1858) **Continuous phase difference measurements of Earth satellites.** J. W. Herbstreit and M. C. Thompson. *Proc. Inst. Radio Engrs.*, **46**, 1535 (*Aug.*, 1958).

(1859) **New missiles and spacecraft challenge telemetry technology.** J. Holaban. *Aviation Age*, **30** (2), 128–36 (*Aug.*, 1958). Lists telemetry systems used by U.S. test missiles, discusses problems of current practice, and indicates future trends.

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for choosing 10 cm. are given. Results obtained from 30 Oct. to 1 Dec., 1957, reported.

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10—BIOGRAPHY AND HISTORY

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(1893) **Dr. Fred L. Whipple: Eyes on the skies**. E. Cromley. *Missiles and Rockets*, **3** (7), 101–2, 105 (*June*, 1958).

The output of books on astronautics and allied subjects is so great that the *Journal* can provide reviews of only a small percentage. All books are, however, noted in ASTRONAUTICAL ABSTRACTS and, for the convenience of readers, the abstract numbers of books will be listed for ease of reference.

The following numbers refer to books noted in this issue: 1459, 1460, 1489, 1490, 1517, 1521–1543, 1568, 1571–1574, 1576, 1577, 1603–1610, 1657, 1658, 1695, 1700, 1702, 1714, 1736, 1740–1749, 1768, 1780, 1782.

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